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ON THE 90TH ANNIVERSARY OF THE BIRTH OF VLADIMIR IL'ICH LENIN

Vladimir Il'ich Ul'yanov (Lenin), whose name will always shine in the constellation of human genius, was born on April 22, 1870 in Simbirsk, a small provincial town in Tsarist Russia.

The greatness of Lenin's revolutionary ideas for the reconstruction of human society on new progressive principles is becoming ever more clear to the workers of the whole world.

On January 22, 1924, just after Lenin's untimely death, the Central Committee of the Communist Party declared,¹ "Never since Marx has the history of the great liberation movement of the proletariat thrown up a figure of such great stature as our departed leader, teacher and friend. Everything that is truly great and heroic in the proletariat—fearless intellect, an inflexible iron will that stubbornly overcomes all obstacles, purposeful hatred to the point of death for slavery and repression, revolutionary fervor which moves mountains, unlimited faith in the creative powers of the masses, vast organizational genius—were all splendidly incarnate in Lenin, whose name has become the symbol of the new world in all quarters of the globe."

Lenin was a great scholar, who combined creative elaboration of the theoretical problems of scientific socialism with great organizational activity for the liberation of the workers and peasants from the capitalist yoke.

Lenin's profoundly scientific analysis of the social and economic factors in the most complex political situation enabled him to find the only correct solution to the strategy and tactics of the class struggle with amazing accuracy.

Thus, in the dark years of the most savage absolutism he saw clearly that the working class struggle could only be successful if a proletarian party was created. Lenin devoted all his activity in this period to the creation of such a party. He worked out the program and organizational structure of the party and defended them in ceaseless discussions with the open and concealed enemies of the working class.

In the revolutionary years of 1905-1907 Lenin worked out the most urgent aspects of the tactics and strategy of the proletarian party in the period of the bourgeois democratic revolution. He developed certain of the opinions of Marx and Engels into the theory of the hegemony of the proletariat in the people's revolution. Lenin showed that the proletariat, as the only consistently revolutionary class, was interested in carrying through the bourgeois democratic revolution to its conclusions so as to prepare the conditions for a socialist revolution. At the same time he developed the hypothesis that there must be an alliance of the working class and the peasantry in which the working class played the leading role. He also completely restated the problem of state power in the form of the revolutionary democratic dictatorship of the proletariat and the peasantry.

All these impressive achievements of Lenin's creative thought were of great importance for the victory of the revolution in Russia and in other countries.

Lenin treated Marxism as the only truly revolutionary theory, and regarded it as a living guide to revolutionary activity rather than as an established dogma. He was the first person to show that socialism could be victorious if there was a socialist revolution in one country. In his article "The United States of Europe Slogan," in which he revealed the law of the unequal economic and political development of the capitalist countries, Lenin commented with the insight of genius "It is possible that socialism can be victorious initially in a few countries or even in one country taken by itself."²

Lenin developed and enriched Marxist teaching. He created the theory of the proletarian revolution, the realization of which brought about the transition from a bourgeois democratic to a socialist revolution in Russia.

Lenin always paid a great deal of attention to agricultural problems. He made a number of noteworthy studies of the agrarian question before the revolution.

His "The Development of Capitalism in Russia" (1899), in which he gives a profound description of the state of the pre-revolutionary

¹"The C. P. S. U. in the resolutions and decisions of its Congresses and Conferences and the Plenary Sessions of the C. C.," 7th edition, part 1, pp. 804-805. 1954.

²V. I. Lenin, Works, 4th edition, Vol. 21, p. 211.

Russian economy, is of particular interest.

This work is of particular importance to scientists. It is a classic example of the application of the Marxist dialectic method to the descriptive analysis of an agricultural economy and the features of its development in pre-revolutionary Russia. Lenin's study is also of interest to soil scientists because it was precisely in the period after agrarian reform that the new problems in agriculture led to the development of contemporary scientific soil science.

Lenin's "The Agrarian Question and Criticism of Marx" (1908) is also of great importance to us for its exhaustive criticism of the "law" of diminishing fertility and its supporters in Russia.

In his great works on agrarian problems Lenin gave conclusive proof of the superiority of large-scale agricultural production. He also showed that under capitalist conditions the development of large farms is unavoidably accompanied by the ruination of the small-scale agricultural producers and by the exploitation of a growing army of agricultural workers. The day after the victory of the Great October socialist revolution, the second Congress of Soviets unanimously adopted Lenin's land decree, under which ownership of land by landlords was abolished and private ownership of the

land was replaced by national state ownership. The adoption of Lenin's decree was of great historic importance for Russia, which was then mainly an agricultural country.

Lenin knew, however, that only cooperation could bring about the transition from small-scale individual peasant economies to large-scale economies organized according to the new socialist principles.

After Lenin's death the Soviet Communist Party, working from the objective laws of social development, led the struggle of the working class and the people for the building of socialism and defended the freedom and independence of the Soviet state in the Great Patriotic War.

The successful conclusion of the building of socialism in the USSR and the outstanding achievements of Soviet science and technology have now made the superiority of a socialist planned economy clear to the whole world.

The whole of progressive mankind celebrates the 90th Anniversary of Lenin's Birth.

In our country the carrying out of the Seven Year Plan—the initial stages in the building of communism—is the best proof of the vitality and creative force of the teaching of Marx and Lenin:

'LABELING' SOIL MOISTURE WITH CHLORIDE ION TO STUDY ITS MOVEMENT UNDER FIELD CONDITIONS

I. S. VASIL'YEV and A. A. RODE,¹ V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

Existing methods for studying the water regime of soils do not give an exhaustive picture even when all the elements are studied and measured. Data normally refer to the soil layer as a whole and the movement of moisture within the soil is inadequately described. It would be interesting and desirable to find a method by which the movement of moisture in the soil could be directly traced. One can suggest the "labeling" of soil moisture by a salt, or more accurately by a non-exchangeable ion. The chloride ion is most suitable, since it is not adsorbed by the soil or it is only slightly adsorbed; and it can be easily determined. It can, of course, only be used when the soil does not initially contain this ion in any noticeable quantity.

To establish whether it was possible to use this method on sod-podzolic soils, one of us (Vasil'yev) set up an experiment on the State crop testing plot on the Kolos kolkhoz in Dmitrov district of Moscow region, where the water regime of sod-podzolic soils under grassland rotation was being studied.²

The experiment was as follows. A level area 4 x 18 m was selected on field 6. The soil was sod-podzolic coarse clay loam on medium clay loam deposit underlayered at a depth of 2-3 m by reddish-brown leached moraine.

When the experiment was started the field was occupied by perennial grasses (clover and

timothy). A 2N solution of calcium chloride was applied to the surface on August 25, 1951 at a rate of 5 liters per 1 m², corresponding to 355 g of chloride ion per 1 m². Ten days after the start of the experiment the top portion of the vegetation on the plot was almost totally destroyed. In 1952 only timothy was re-established and a considerable admixture of couch grass appeared. In 1953 the amount of couch grass was considerably increased. In 1954, couch grass predominated. The air-dry weight of the tops varied between 30-40 cntr/ha in 1952-53 and 24 cntr/ha in 1954. Spring wheat was sown on the plot in the spring of 1955; the yield of the tops was 50 cntr/ha.

The soil moisture and the chloride ion content were determined periodically from the autumn of 1951. Four soil samples were taken on each occasion for analysis. The content of chloride ion was determined in the normal manner in water extracts from the same samples in which moisture was determined. These samples were quantitatively transferred from the aluminum boxes to flasks for preparation of the water extract.

The accuracy with which the chloride ion was determined can be assessed from the following levels for the total content of chloride ion at a later determination period (July 6, 1955) in a 4 m layer:

Sample hole	Total content of chloride ion
1	299 g/m ²
2	302 "
3	292 "
4	304 "
Average	299 "

We should clarify that the levels of total contents of chloride ion for each sampling hole were obtained by summing more than 30 values for the chloride ion content in the 10 cm layers. It can be seen that the deviations between the parallel determinations is insignificant.

We shall first examine Table 1 in which the total contents of chloride ion at the successive sampling periods are given. As mentioned previously, 355 g of chloride ion per m² were applied. In the first 3 periods of the determination, up to April 1952, almost all the chloride ion was detected in the soil: 339, 333 and 340 g/m².

¹ Vasil'yev conducted the experiments described in this article between 1951 and 1955. After his death in 1956 only rough materials of the experiment, insufficient for the compilation of a paper, were found. A folder containing the fully processed materials and the first pages of the article has only recently been discovered. Since this paper has been largely written by me, I consider that I have both the right and the duty to affix my name as a co-author, since responsibility for the content of the article and its conclusions rests with me. A. R.

² The results of this study are set out in Vasil'yev's "The water regime of sod-podzolic soils in a grass rotation," published in 1956 in "The fertility of sod-podzolic soils" (Izd. Akad. Nauk SSSR). This and other articles in the same collection contain a detailed description of the soils, which is therefore not given here.

Table 1

Total content of chloride ion

Observation date	1951		1952				1953		1954		1955
	30.X	30.XII	10.IV	11.VI	19.IX	26.X	2.IV	8.X	2.IV	10.VII	6.VII
Layer, cm	0-40	0-60	0-50	0-140	0-150	0-150	0-150	0-250	0-190	0-250	0-400
Total content of chloride ion, g/m ²	339	333	340	264	258	234	234	291	86	185	300

Subsequently, the amount of chloride ion detected decreased and varied between 234 and 264 g/m². In the autumn of 1953, 291 g/m²; in 1954, 86 g/m² in the spring and 185 g/m² in the summer; and in the summer of 1955, 300 g/m².

The difference between the quantity of chloride ion determined and that applied is due to the fact that the determination was conducted in a layer that was too thin. When determination was conducted to greater depths (autumn 1953 and

summer 1955), approximately 300 g/m² of chloride ions were detected, i.e., much closer to the amount applied. A secondary cause of the missing amount of chloride ion may be its absorption by plants.

We shall examine the movement of chloride ions in the soil profile. The distribution of chloride ions in the soil layer in the autumn periods in 1951, 1952, and 1953, and in the summer periods in 1954, and 1955 is shown in

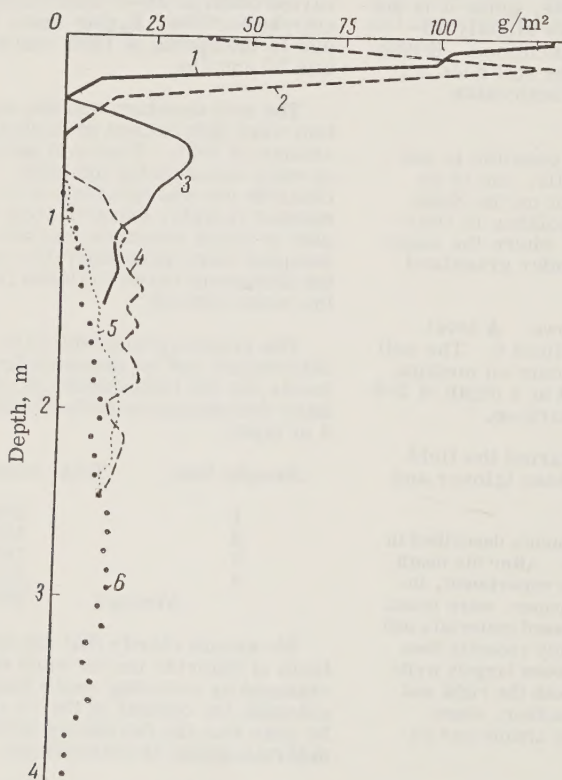


Fig. 1 - Distribution of chloride ion in the soil layer in autumn or spring for each year of observation.

1 - Oct. 30, 1951; 2 - Dec. 30, 1951; 3 - Oct. 26, 1952;
4 - Oct. 8, 1953; 5 - July 10, 1954; 6 - June 6, 1955.

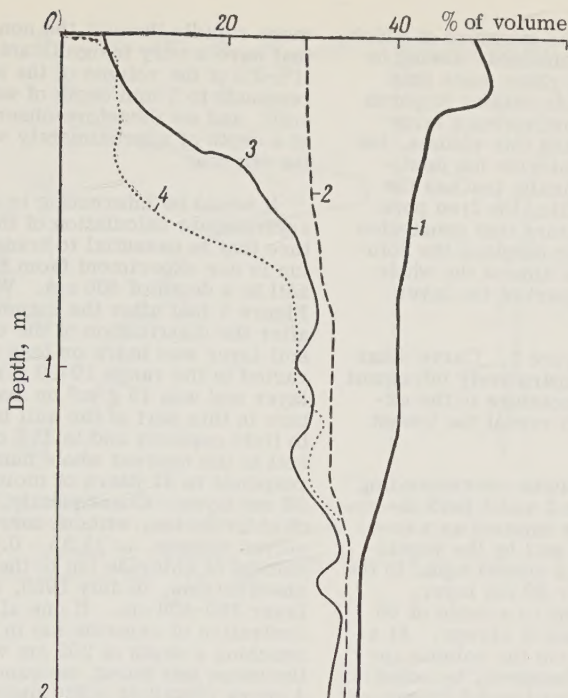


Fig. 2. - Variation throughout the soil profile of the differences of moisture at varying moisture contents.

1 - Total pore space; 2 - pore space corresponding to minimum field moisture capacity; 3 - pore space filled with water at minimum moisture observed in the experiment of July 10, 1954; 4 - pore space filled with water at the lowest possible moisture observed on July 14, 1951.

Fig. 1.

In 1951 the autumn rains carried the chloride ions to a depth of 30 cm, but the main mass remained in the upper 20 cm, i.e., in the plowed layer. By the autumn of 1952 the upper 40 cm of the soil was almost totally leached of the chloride ion, which had penetrated to a depth of more than 150 cm. By the autumn of 1953 the chloride ion had been totally leached from the upper 80 cm layer and extended down to more than 250 cm. Its subsequent leaching occurred much more slowly. In the following year, by the summer of 1954, the thickness of the layer from which chloride ion had been leached had only increased by 10 cm. In the course of another year the upper boundary of the layer containing chloride ion remained in the same position. There was a slight decrease in the content of chloride ion in the upper part of this layer alone in the following year, which pointed to continued leaching. The depth to which the chloride ion had extended in the soil profile by the summer of 1955 exceeded 4 m.

Bearing in mind that chloride ion moves with liquid water in the soil, we can draw the following conclusions from the facts just established.

Firstly, we see that the behavior of the chloride ion fully confirms the hypothesis that sod-podzolic soil and the underlying soil material strata are annually leached by the moisture of atmospheric precipitation. This is the only explanation for the observed leaching of the chloride ion to a depth of 4 m in 5 years.

Secondly, we see that the movement of the chloride ion (and consequently of the soil solution containing it) is fairly rapid. In the first year even, a considerable amount of the soil solution containing chloride ion and, therefore, originating in the surface layer of the soil was transferred to a depth of more than 2.5 m.

Thirdly, we can state that the movement of chloride ion in the upper meter layer, or thereabouts, is considerably more rapid than in the lower layers. In the first 2 years an 80 cm layer was completely leached of chloride ion, while in the subsequent 2 years the thickness of the layer leached of chloride ion only increased by 10 cm. The fact that chloride ion is leached from the lower part of soil more slowly than from the upper part of soil is due to the fact that the upper part of the soil layer, i.e., the soil layer itself, as can be seen from Figure 2, dries out during the growing period much more intensively

than the underlying layer, the moisture of which is generally speaking little affected. Owing to this drying, which may take place more than once a season, a considerable volume of pores are emptied and capable of receiving a large amount of moisture. In filling this volume, the moisture also carries the chloride ion downwards with it, i.e., energetically leaches the soil. Lower down the profile, the free pore space is small and the moisture that penetrates through can, primarily, only displace the solution that constantly occupies almost the whole volume of the pores in this part of the layer ahead of it.

This is illustrated in Figure 2. Curve 4 has been given because our comparatively infrequent determinations of the soil moisture in the experimental plot might fail to reveal the lowest moisture values.

Figure 2 shows that a volume corresponding to the space between curves 3 and 1 (and ultimately between 4 and 1) is emptied as a result of the drying out of the soil by the vegetation. This volume, which is almost equal to the total pore space in the upper 20 cm layer, rapidly decreases downwards to a depth of 60 cm, after which the decrease is slower. At a depth of approximately 150 cm the volume approaches zero. It should, however, be noted that the space between curves 1 and 2 ("non-capillary porosity") corresponds to the volume of pores primarily between the aggregates in which the soil solution appears for only a short time when moistening is particularly intense. At other times the soil solution and its content of chloride ion (in our experiment) is to be found in the "capillary" pores, the total volume of which in Figure 2 lies to the left of curve 2. Therefore, the free volume that occasionally develops when the soil is dried out by plants and from which chloride ion can be easily and rapidly leached when it is filled with moisture, is shown in Figure 2 by the space between curves 2 and 3 (between 2 and 4 for limit of low moisture). It was from this volume, which decreases to nothing at a depth of 60-70 cm and which makes up 87 mm depth of the water in the upper 60 cm layer, that the chloride ion was rapidly displaced by the end of the second year of the experiment (Fig. 1). Its subsequent leaching must inescapably proceed more slowly. In the range of depths from 60 to 150 cm, where non-capillary porosity (the space between curves 1 and 2 in Fig. 2) is still relatively great, moisture can rapidly fill the pores between the aggregates, but in this case chloride ion will only be leached by diffusion from the volume of the soil solution filling the pores within the aggregates into the volume of solution filling the pores between the aggregates. The free volume of capillary pores at a moisture corresponding to curve 3 is equivalent only to 23 mm depth of water, and of the non-capillary pores to 66 mm depth in the layer 60-150 cm. This diffusion can only take place in the brief periods when the pores between the aggregates are full of water. Non-capillary pores are practically absent from the layer at 150 cm and below, and the leaching of chloride ion is almost exclusively due to pressure on the soil solution in the pores within the aggregates by the moisture from above. It is only a very small amount of chloride ion that can be leached

more rapidly through the non-capillary pores that have a very insignificant total volume (1%-2% of the volume of the soil, which corresponds to 7 mm depth of water to 50 cm of soil), and we therefore observe its appearance at a depth of approximately 4 m at the end of the 4th year.

It would be interesting to attempt even an approximate calculation of the amount of moisture that is essential to transfer the chloride ion in our experiment from the surface of the soil to a depth of 400 cm. We can see from Figure 1 that after the autumn of 1953, i.e., after the distribution of the chloride ion in the soil layer was more or less even, its content varied in the range 10-20 g/m² in a 10 cm layer and was 15 g/m² on average. The moisture in this part of the soil layer corresponds to field capacity and is 35% of the volume of the soil to the nearest whole number. This corresponds to 35 liters of moisture in 1 m² of a 10 cm layer. Consequently, the concentration of chloride ion, without correction for undissolved volume, is $15:35 = 0.43$ g/l. The total content of chloride ion in the last period of the observations, in July 1955, was 220 g/m² in the layer 200-400 cm. If one allows that the concentration of chloride ion in the soil solution reaching a depth of 200 cm was always close to the value just found, we can conclude that in the 4 years, $220:0.43 = 510$ liter or 510 mm reached a level of below 2 m from the upper layers of the soil. This corresponds to a yearly average of 125 mm; this is the value for ground flow. This calculation is, of course, approximate and only indicates the order of magnitude.

Let us examine two particular cases of the movement of soil moisture, which can be clarified on the basis of a combined study of the behavior of chloride ion and changes in moisture

Figure 3 shows the distribution of chloride ion (on the left) and moisture (on the right) in July and September, 1952. The moisture content is expressed as percentages of the minimum field capacity. It is clear from Figure 3 that between July 11 and September 19, there was considerable and fairly even drying of the soil throughout the profile to a depth of 35 cm and that the total depth of drying was greater than 70 cm. In the 0-35 cm layer moisture decreased to 50%-60% of field capacity. The distribution curve for chloride ion shows that the ion moved from the 35-65 cm layer in the same period of time, where its concentration was considerably reduced, to the 5-35 cm layer, where it increased considerably. Note that in July chloride ion is totally lacking in the layer down to 25 cm. Consequently, there are times during the growing period in sod-podzolic soils when there is a rise of suspended rather than perched moisture. This shows that the initial July moisture of the layer from which the chloride ion moved upwards did not exceed field capacity. Having used up all or the greater part of the available moisture in the 0-35 cm layer the plants created a considerable suctional force in this layer, which caused the upward movement of liquid moisture from the underlying 30 cm layer.

The second case relates to the winter and is illustrated by Figure 4, in which the distribution

"LABELING" SOIL MOISTURE

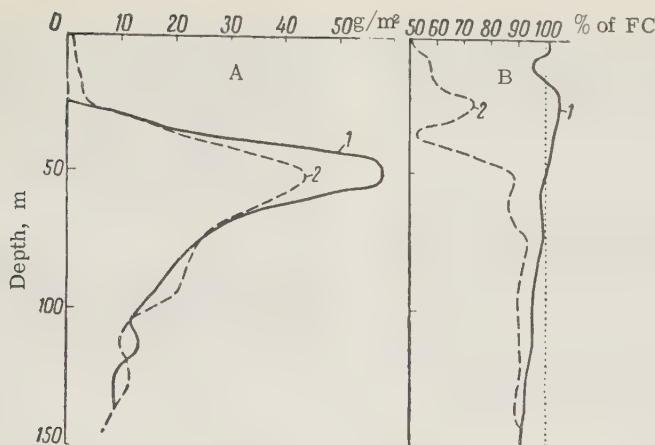


Fig. 3 - A - Change in the distribution of chloride ion; B - change in relative soil moisture content; summer of 1952.

1 - content of chloride ion and moisture on July 11, 1952; 2 - the same on Sept. 19, 1952.

of chloride ion and moisture in the soil profile is given for late October, 1952 and early April, 1953. As can be seen from Figure 4, the initial autumn moisture throughout the 150 cm layer was almost the same as field capacity, i.e., there was only suspended moisture in the soil. Towards the spring the upper 35 cm layer was considerably enriched with moisture at the expense of the 35-150 cm layer. The chloride ion content curve shows that a considerable amount of chloride ion moved during this time from the 40-100 cm layer to the 0-40

cm layer. The chloride ion penetrated even to the uppermost surface layer of the soil, although it had been leached from the entire upper 35 cm layer in October, 1952.

Many investigators have observed the rise of water in the winter when autumn soil moisture is relatively high. For a long time it was not clear whether this moisture moved as a liquid or as vapor. The considerable quantity of transferred water and certain laboratory experiments pointed with a high degree of

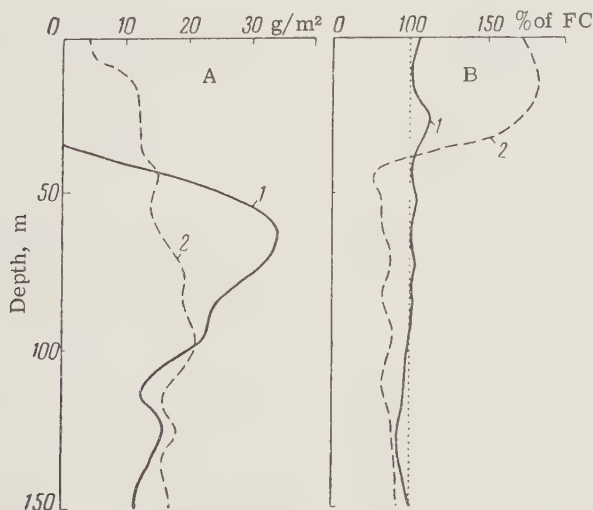


Fig. 4 - A - Change in the distribution of chloride ion; B - change in soil moisture content; winter of 1952-53.

1 - content of chloride ion and moisture on Oct. 26, 1952; 2 - content of chloride ion and moisture on April 2, 1953.

probability to the idea that the movement was in the liquid state. Our experiments under field conditions fully confirm this hypothesis, since chloride ion can only move upwards in solution, i.e., associated with liquid water.

Conclusions

1. The application of salts containing chloride ion to the soil, accompanied by subsequent combined determination of its quantity in the soil profile moisture, is promising for the study of soil moisture phenomena not revealed by the standard methods.

2. Use of this method of sod-podzolic soils confirms the view that the entire soil layer was periodically wetted by the atmospheric precipitation and that part of this moisture forms

ground-water flow. The soil on a medium clay loam deposit was entirely leached of the chloride ion in 2 years. This shows that the whole soil solution in the layer had been totally replaced in this period. Subsequent leaching of the soil layer is considerably retarded. Within 4 years, however, the chloride ion applied to the surface of the soil had penetrated to a depth of not less than 4 m.

3. It has also been shown that both in summer and in winter there can be periods in the water regime of sod-podzolic soils under grasses when there is a rise of liquid water into the upper layer from the underlying layers.

Received November 10, 1959

TRANSLATIONAL MIGRATION OF CAPILLARY-SUSPENDED MOISTURE IN SANDY SOIL MATERIALS

V. YA. STAPRENS

If we consider the moisture in the soil from the point of view of its adhesion to the skeleton, then in the case of sandy soil we may properly distinguish the following categories of water (disregarding water in the vapor, frozen, and chemically-combined states): 1) Hygroscopic (adsorption-bound) water; 2) Film (molecularly-bound)¹ water; 3) Capillary (capillary-bound) water; and 4) Free water.

The transition points between the individual categories in this communication follow the designations of A. F. Lebedev: between 1 and 2, the maximum hygroscopicity (MH); between 2 and 3, the maximum molecular moisture capacity (MMMC); between 3 and 4, the transition from negative pressure to positive pressure in the water.

We note that in such a breakdown capillary-immobile moisture is conventionally referred to the category of bound water.²

In the absence of a sufficient gradient of capillary pressure, the moisture in the soil moves directly downward under the influence of gravitational forces, without losing its capillary association with the skeleton of the soil, provided it does not meet conditions in its path that hinder this movement. Above the barrier, surface horizons or zones, capillary-bound moisture is formed. We distinguish two types of barriers: 1) perched and 2) suspended capillary water.

The author distinguishes two types of perched capillary water. The first type consists of capillary water in horizons lying above the water table, and the second, those lying above an absolute or relative water-barrier.

Capillary-suspended water is held in the soil because of the presence of a force field which counteracts the gravitational force. If in a

layered stratum the capillary potential of a higher-lying layer K_1 is greater than the potential of a lower-lying layer K_2 , then if $K_1 \geq K_2 + P$, where P is the hydrostatic pressure acting vertically downward on the particle of water, the latter will be firmly held in the higher-lying layer, i.e., will be suspended, as it were. K_1 and K_2 are measured by the respective heights of capillary rise, h_{K_1} and h_{K_2} , while P is measured by the corresponding height of a water column h . Hence we may write the condition for the suspension in the form $h = h_{K_1} - h_{K_2}$, i.e., the maximum thickness of the layer of capillary-suspended moisture in the soil is equal to the difference between the heights of capillary rise in the upper and lower layers. Practically, because of the occurrence of capillary hysteresis, the value of h can be somewhat larger than that shown. The moisture in the zone of suspended moisture is distributed along a definite curve, suggesting the upper portion of the capillary curve of the soil (the curve of d'Andrimont).

For the case of sandy soil materials, we suggest distinguishing four basic types of capillary-suspended moisture. The first type forms in a stratified soil, if a finely porous layer is underlain by a more coarsely porous layer, or a layer of soil by an air space. The second type occurs with the percolation of water into the soil, if the initial soil moisture is low (appreciably less than the MMMC) and the thickness of the percolation wave does not exceed definite limits. The third type is formed when a percolation wave "settles" under known conditions in a zone of perched capillary moisture. The fourth type, capillary-immobilized (wedged) moisture, as was already mentioned, is conventionally referred to the category of bound water.

This paper is devoted to a consideration of the particular question of the dynamics of capillary-bound moisture. Capillary and gravitational forces play the principal part in the transfer of this moisture. We can, of course, speak of "capillary" transfer (capillary rise, capillary movement, etc.), but under natural conditions only in a conditional sense, since every movement occurs in the field of gravitational forces. The designation "capillary" indicates only that capillary forces play an important role in the process and that their activity is of primary interest to us. But when the hydrostatic pressure remains constant and

¹The name "bound water" is usually understood to refer to the first two categories.

²The term bound water should be applied only to that part of the moisture which is bound by sorption forces to the surface of soil particles. In this sense the moisture retained by capillary forces, i.e., capillary moisture, is not bound. Ed. note.

relatively small, for example, in the horizontal direction and in a thin stream, in the presence of a capillary pressure gradient we obtain capillary movement in a relatively pure form.

The capillary movement of water is a very complicated process. The movement is affected by, in addition to capillary and gravitational forces, the nature of the porosity, moisture content, and wettability of the medium, the temperature and the temperature gradient, hysteresis phenomena, the presence of entrapped air, etc. The nature of the water supply has an exceptionally large effect on the rate of moisture movement. This is the basis for our distinction of two basic types of capillary moisture movement: 1) capillary absorption and 2) capillary resorption.

In capillary absorption the water is supplied either by free water or by the amount of available capillary-bound moisture that are infinitely large for the given case. The moisture and pressure at the source remain practically constant. In capillary resorption the water supply is provided exclusively by the capillary moisture content present in the vicinity. The advance of the wetting front is necessarily associated with a reduction in moisture and the exertion of negative pressure at the source. At one and the same point, in the presence of such a moisture gradient, the rate of capillary absorption can be hundreds or thousands of times greater than the rate of capillary resorption. Therefore, we must take into account the sort of capillary movement with which we are dealing.

The transfer of capillary-bound moisture can occur also in the absence of a capillary pressure gradient in the direction of flow, as the result of a gradient of gravitational forces, for example in a sloping region. This form of movement we have called translational (from the Latin word *translatio*—transfer from place to place) migration or transfer. Translational migration differs essentially from capillary sorption or resorption in that, in the first case, the pressure gradient (and consequently, also the rate of flow in a homogeneous medium) along the path of flow remains constant when the flow has been established and the slope does not

vary.

Translational movement of perched capillary water of the first type in a sloping region is well known and we shall not discuss it at length. Zones of perched capillary water of the second type are essentially immature or deteriorated zones of the first type. Therefore, translational migration in the first is qualitatively the same as in the second.

The problem of the translational movement of suspended water is more complicated. At first glance it might seem that this is not possible, since the single motive force of transfer in the ordinary sense can only be gravity, directed vertically downward. If this force is not sufficient to overcome the resistance of other factors and the moisture remains (often very firmly) in the suspended state, then it is difficult to imagine that this same moisture would move, overcoming the much greater resistance of soil friction under much smaller pressure gradients. Actually translational movement in a sloping region is not only possible but also necessary, as the following considerations show.

Let us suppose that in a layer of soil consisting of two homogeneous layers there is a horizontal zone of suspended water (Fig. 1, I). When a condition of equilibrium has been established, the capillary forces here are constant throughout the horizontal extent of the layers. Since $H = hK_1 - hK_2$, then h , i.e., the thickness of the zone, is also the same everywhere.

Let us consider a particle of water Δb in a vertical section of soil. The water particle is acted upon: on the one hand, by the resultant of the gravitational forces G_1 , directed vertically downward, and on the other hand, by the resultant of the capillary forces K . The direction of the latter, as the resultant of a force field, can only be normal to the isopotential (in our case also isoconcentric) surface, i.e., vertically upward. If the particle is motionless, then $K = G_1$. Both forces acting along a single line in opposite directions cancel each other.

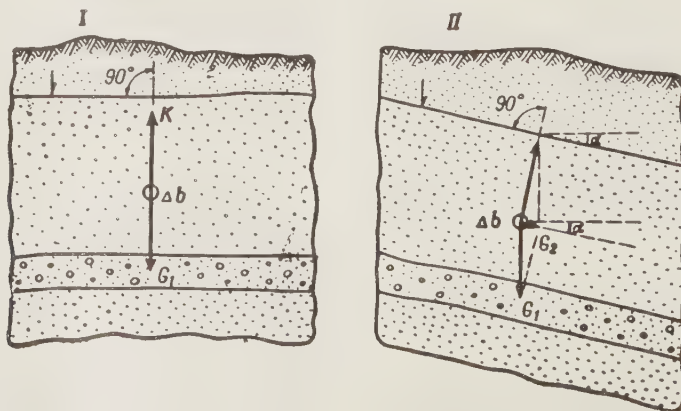


Fig. 1. - Reaction of capillary and gravitational forces in horizontal and sloping zones of capillary-suspended moisture.

If the zone is sloping at some angle α to the horizontal direction (Fig. 1, II), then the state of equilibrium is disturbed, since the forces are not acting along a single line. G_1 as we said previously, acts vertically downward, and K acts normally to the new direction of the zone. The geometric sum of the forces K and G_1 gives a force G_2 which will tend to displace the particles downward along the slope parallel to the direction of the zone. Since K acts along a normal to the isoconcentric surface not only in zones of suspended water but also in every wet capillary-porous medium, then translational movement is necessary in every homogeneous medium with a sloping distribution of moisture, for example, in the descending movement of a percolation wave in areas of sloping relief.

The numerical value of G_2 , as can be seen from the diagram, is equal to $G_1 \sin \alpha$. The expression $G_1 \sin \alpha$ is known from hydraulics, where it designated the magnitude of the motive force in a flow of free water. Hence suspended moisture in translational flow moves principally according to the same law as perched free water.

Let us consider one more argument which leads to a conclusion of considerable practical interest.

As we know, moisture in a zone of suspended water is distributed according to a definite curve, a definite degree of saturation corresponding to each height above the level of the basic zone. If the soil in relation to some particular height is supersaturated, it will give up water; if it is undersaturated, it will absorb water. Let us consider an element of soil in a sloping zone of capillary-suspended moisture (Fig. 2, I), located at a height h above the base level and saturated with moisture to a corresponding extent. In comparison with an adjacent height h_1 , the element is incompletely saturated and should absorb moisture, but in comparison with h_2 , it is supersaturated and should give up moisture. Thus through this element there should be a continuous flow of moisture from

left to right, i.e., in the direction of the slope. These considerations are applicable to any element of the zone.

Let us assume further that under an element of soil there is a partition (Fig. 2, II). With respect to the level of the sector to the right of section m-n, the entire sector to the left of the partition is supersaturated. Since the capillary-suspended moisture is free to migrate upwards, it will migrate over the partition from left to right. Similarly, suspended moisture is free to migrate across obstacles under natural conditions, for example, across a draining layer or a water barrier.

Numerous experiments under laboratory and natural conditions show that the scheme presented for the transfer of capillary-suspended moisture corresponds completely to reality. We have more than once heard the objection that the foregoing considerations are true only for individual sections or small sectors of zones of suspended moisture, but not for zones as whole. Thus, for example, if in a zone of suspended water (Fig. 3) we consider section m-n, then at point A the hydrostatic pressure ($p' = gh'$) actually can be offset by the capillary potential of the zone. The same can be said for section o-p. But the zone as a whole is not the individual section, but a single hydraulically integral system. Therefore, the hydrostatic pressure at point B will equal not gh'' , but $g(h' + h'') = gH$. If $h' + h'' > h_K - h_K$, which is determined only by the distance between the two sections, then at point B there should begin a release of moisture to the underlying stratum, which should lead to the collapse of the whole zone.

This objection, which at first glance seems substantial, is justified only in the field of hydrostatics. In this case we are concerned with a hydrodynamic process. Here the excess hydrostatic pressure gives such a rate to the movement of the moisture that in the given sector it is discharged completely and as a result the hydrostatic pressure at point B remains

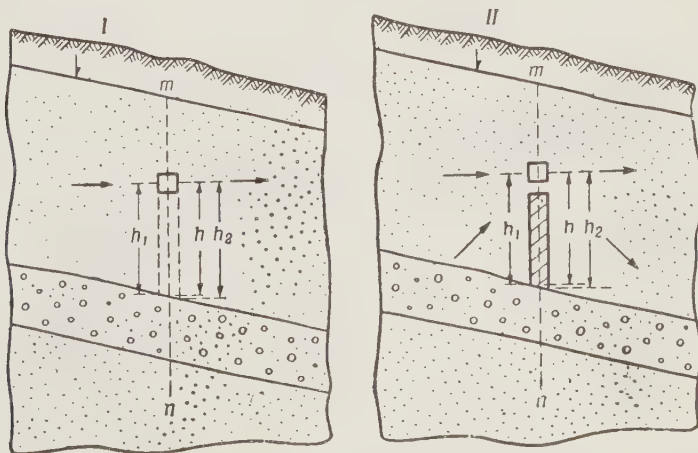


Fig. 2. - Migration of capillary-suspended water with a barrier to path of flow.

equal to gh'' . The latter is demonstrated by the experiment below.

In the model, the dimensions and shape of which are shown in Figure 4, there is a zone of suspended capillary moisture of the first type in a layer of fine-grain sand on a layer of coarse-grain sand. The distance from the upper end of the trough to the point of measurement of the pressures, D , is 270 cm, the angle α is 18° , $\sin \alpha$ is 0.31, and h is 34 cm. The moisture at any point in the upper layer, according to a law of hydrostatics, should be subject to a positive hydrostatic pressure from the moisture in the higher part of the trough (Fig. 4, to the left of the points of measurement). The magnitude of this pressure should be equal to $(D \sin \alpha + 3)$ cm of water; at point 1, $(270 \times 0.31 + 3) \approx 87$ cm of water. In addition, moisture located at a height h above the line connecting the level of free water with the end of the trough should, at

the same point 1, be subject to a capillary pressure (negative) of -34 cm of water. The total pressure is $+87 - 34 = +53$ cm of water. Consequently, from the point of view of hydrostatics, the capillary-bound water should be converted to the free state, and the zone of suspended moisture should disappear.

Actually the picture is entirely different. When, after the establishment of translational moisture movement, we measure (tensiometrically) the pressures at points 1 and 2, we find that the pressure at point 2, H_2 , is equal to -17.4 cm of water, while that at point 1, H_1 , is -32.6 cm of water, i.e., practically equal to h . The negative pressure H_1 exceeds H_2 by $32.6 - 17.4 = 15.2$ cm of water. Since point 1 is located about 3 cm below the surface of the zone, then, with zone thicknesses up to about 18 cm, loss of water to the underlying layer is impossible. On the contrary, each drop of water

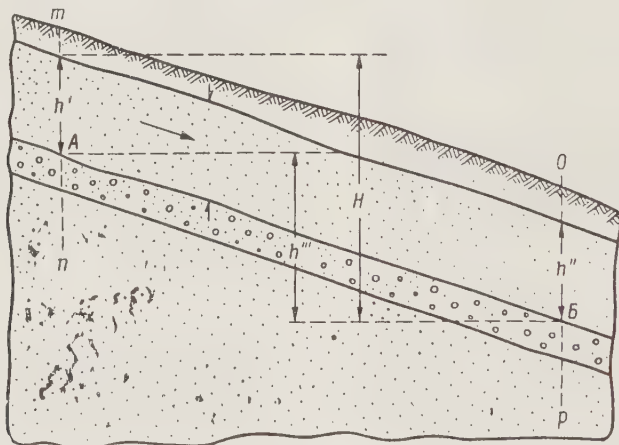


Fig. 3. - Hypothetical hydrostatic pressure in a sloping zone of capillary-suspended moisture.

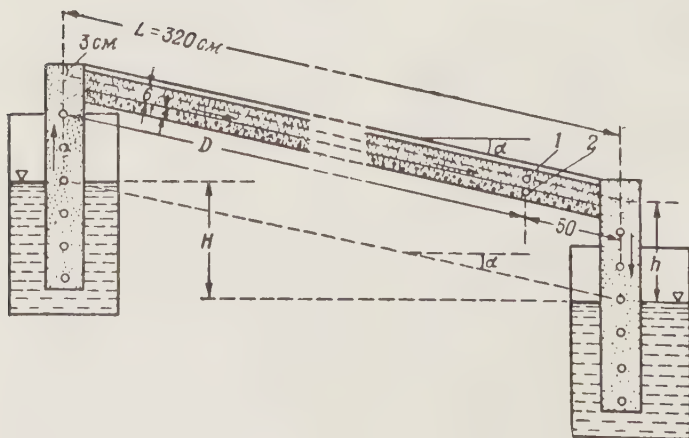


Fig. 4. - Model for studying translation transfer of capillary-suspended moisture.

falling by any route to the underlying layer will rapidly be sucked up by the upper layer. Moisture contents at equilibrium in the layers will be sucked up by the upper layer. Moisture contents at equilibrium in the layers will be, respectively: $W_2 = 2.6\%$ and $W_1 = 17.1\%$ by weight.

In determining the speed of flow of the capillary-suspended moisture, the mathematical dependence established for perched capillary water holds. Here we might adopt the formula suggested by S. F. Aver'yanov

$$K_w = K_f \frac{W - W_0}{n - W_0}^{3.5},$$

where K_w is the capillary water conductivity, K_f is the coefficient of filtration, W is the mois-

ture content, n is the porosity, and W_0 is the maximum molecular moisture capacity of the soil in the zone (W and W_0 by volume). It should, however, be mentioned that in sandy soil materials at average pressure gradients the values of K_w obtained by this formula are somewhat too low. In particular, in the example cited ($W = 26.5\%$, $W_0 = 4.0\%$, $n = 41.5\%$, and $J = 0.31$) the discharge of the trough was $81.7 \text{ cm}^3/\text{hr}$, while calculation by the formula mentioned gives a value of $78.3 \text{ cm}^3/\text{hr}$.

A layer of soil is always stratified to some extent, and this is necessarily associated with the horizons of suspended moisture. Usually these horizons are sloped to one side or the other. Hence, translational movement of capillary-suspended moisture is a universal phenomenon playing a significant role in the water regime of ground layers.

ROLE OF INVERTEBRATES IN THE DECOMPOSITION OF OAK LITTER

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Invertebrates are of immense importance in soil formation and play a major part in improving soil fertility.

With rare exceptions, soils are abundantly populated by invertebrates, especially by the small arthropoda (collembola, ticks), roundworms (Nematoda) and protozoa. An area of 1 m² of soil may contain up to a million collembola and ticks, more than 14 million Nematoda, (19) and hundreds of thousands of protozoa in every gram of the surface soil (4).

One of the most important factors in soil formation and one of the stages in humus formation is the decomposition of organic substances (plant and animal residues) (9, 15). In this process invertebrates play a very important part.

Of major significance in the decomposition of dead plant residues are the ground molluscs, the Nematoda, the enchytrae, the rain worms, the myriapod Diplopoda, wood lice, the ticks Oribatei and Tyroglyphoidea, collembola and fly larvae. There have been several attempts at a quantitative estimate of the activity of particular species or groups of soil invertebrates in the decomposition of forest litter, mainly under laboratory conditions (6, 7, 12, 16, 17, 21, etc.). It is important to estimate the activity of invertebrates under natural conditions excluding the part played by vertebrate animals in the litter decomposition but including the part played by bacteria and fungi. This was the purpose of the present work.

Location and Methods of Research

In 1958 we investigated the activity of soil fauna in the decomposition of oak litter in comparatively dry goutweed-infested oak stand on thick, humus-rich chernozems in the Central Chernozem Reservation near Kursk.

M. S. Gilyarov suggested using naphthalene in order to exclude the invertebrates from the decomposition process. Our own research has confirmed his finding that naphthalene drives away the animals and completely excludes them from taking part in the decomposition process, whereas if Kholodnyy et al. (14) and Fedorova (13) are correct it does not prevent the decomposition caused by the bacteria and fungi.

Kholodnyy and co-workers (14) set up tests in which they inoculated mineral gels with chernozem and podzolized forest soil aggregates. A variety of bacterial colonies very quickly appeared in the naphthalene vapors from the gel in the neighborhood of the soil aggregates. It was found that these microorganisms could destroy even the naphthalene itself.

The fact that in our own investigations we found pilei, which are one of the main fungus agents of forest litter decay (15), as well as bacteria developed even in the absence of naphthalene, indicates that decomposition caused by fungi and bacteria continues to occur in the presence of naphthalene. M. M. Zozulina, a microbiologist of the Central Chernozem Reservation, confirmed that bacteria of the same type as those found in ordinary litter were present in litter (oak leaves) treated with naphthalene for four months, by inoculating cultures on meat peptone agar.

Two series of tests were started in the second half of May in more or less identical plots of the oak stand, the first on litter which had already consolidated before the tests were set up and the second on leaves which had remained on the trees throughout the winter and been removed in spring before shedding. A quantity of 373 g of spring-fallen leaves in air dry conditions was piled on soil which had been carefully cleared of old litter (according to unpublished figures obtained by Ye. A. Afanas'yeva and V. V. Gertsyk this is the average amount of litter per m² of oak stand in the reservation). In both series the litter on the soil surface was covered with wooden frames 1 m² in dimension, with walls 15 cm high, tightened with a caprone sieve with 2 x 2 mesh. The plants were left under these frames and as they grew up from under the sieve, the invertebrates could readily penetrate the frames and escape from them. In both series half the number of frames were kept as controls; from May 21 onwards naphthalene was poured into the experimental frames in such a way that the litter surface was always more or less covered by a thin naphthalene layer. The naphthalene volatilized fairly quickly in the open air and 2.5 kg per m² were

¹Two varieties of oak (*Quercus robur* L.) are found in the Central Chernozem Reservation: one sheds its leaves in autumn, the other in spring.

DECOMPOSITION OF OAK LITTER

used during the 140 days of the experiment.

A population count of the litter was taken once every 10 days in the test area but at a fair distance from the actual test points so as to avoid the influence of the naphthaline. The larger forms were counted by manual selection on 32 quarter-m² (50 x 50 cm) plots every 24 hours. The smaller population (ticks, collembola) were counted by means of eilectors set in the sun (10 samples to every 100 cm²).

Laboratory experiments (2 replicates) in treating the litter with *Tipula scripta* Meig., *Sarmatiulus kessleri* Lohm, and *Tracheoniscus rathkei* Brandt larvae were made at the same time, using leaves from the litter which had begun to decompose as the test material. A sample of leaves which had been thoroughly dried in the sun was placed in a crystal pan loosely covered with a lid and wetted with rainwater. A known number of invertebrates of the same species, which had been left without food for several days so as to clean out the intestines, was placed on these leaves. The animals were again left without food after they had been allowed to feed on the leaves and the excrements produced during this period were compared with those produced during the test period. The experiment was as a rule continued for 10 days. The animals were kept in a room at more or less constant temperature.

Invertebrates of the same species were reared in the laboratory at the same time for the purpose of obtaining a sufficient quantity of excrement for chemical analysis. The excrements were collected after the invertebrates had been kept for 1-1/2 months and immediately dried. On the advice of M. M. Kononovaya the excrement was extracted with saturated solution of sodium fluoride (NaF solution was used in order to detect humic substances in the ex-

crements).²

Role of Invertebrates in the Decomposition of Oak Litter

Three experimental and control counts were made in each series over a period of 140 days in the autumn (from May 21 to October 8), the leaves being carefully collected and dried. The results are given in Table 1.

In the first series (in spring a known quantity of leaves were taken from the trees and heaped on clean soil) 9% of the litter disappeared when the invertebrates were excluded and 55.3% when they contributed to the decay.

When the invertebrates are excluded, then the bacteria and fungi alone cause only about one-tenth of the oak litter to decompose, whereas more than half of it decays when soil animals are operating in conjunction with the bacteria and fungi.

The results of the second series confirm those of the first. As in the first series, also in the second (with the old, caked litter) where the original quantity of material was unknown, the amount of litter fall in the experiment (with the naphthaline) was found to be nearly twice as great as in the control. In the first series 339.3 g of leaves were left after decomposition without participation by invertebrates and 166.8 g after decomposition in which invertebrates

²The work was done by a joint team consisting of Ye. A. Afanas'yeva, soil scientist, and A. M. Semenovaya-Tien-Shanskaya, geobotanist. The invertebrate determinations were made by T. S. Perel' (rain worms), I. Ye. Lokshina (myriapods), Ye. V. Borutskiy (wood lice) and N. P. Krivosheynaya (fly larvae).

Table 1

Role of soil invertebrates in the decomposition of oak litter

Series	Treatment	Original quantity of litter	Weight of litter remaining after 140 days	Amount of litter decayed in 140 days		Difference in the quantity of litter remaining in the experimental and control lots	
				Grams	Original quantity, %	Grams	Experimental quantity, %
First Spring litter	Without invertebrates	373	339,3	33,7	9,0	172,5	100
	Control (with invertebrates)	373	166,8	206,2	55,3		50,8
Second Old litter	Without invertebrates	?	470,1	—	—	228,4	100
	Control (with invertebrates)	?	241,7	—	—		48,6

Note: Comma represents decimal point.

Table 2

Litter population in oak forest of Central Chernozem Reservation in 1958 (number per m²)

Animals	21-22.V	31.V-1.VI	10-12.VI	20, 22-23.VI	10-11.VII	20-21.VII	2-4.X	20, 22.X
<i>Dendrobaena octaedra</i> Sav.	17,3	11,5	167,7	157,1	171,0	9,3	61,4	55,5
Others (mainly <i>Eisenia rosea</i> Sav.)	6,7	1,4	7,0	20,2	16,8	1,1	5,0	1,8
Total rain worms	24,0	12,9	174,7	177,3	187,8	10,4	66,4	57,3
Enchytreidae	80	70	200	250	330	30	1500	2570
Thread polypods	4,1	3,3	3,9	2,9	2,1	0,8	3,5	0,7
All diplopods	4,5	3,3	5,1	3,6	4,3	0,9	4,6	0,8
Wood lice	4,4	4,7	7,7	9,7	9,3	6,0	2,0	1,3
Leatherjacket larvae	1,5	1,9	2,1	3,8	2,0	1,3	0,1	0,9
All dipterous larvae	2,0	2,4	2,3	11,3	10,0	1,4	4,0	3,0

Note: The October Enchytreidae count was made by manual selection of 100-cm² samples (10 samples per count). The values for the preceding month were taken from the small animal count made with electorbs but gave slightly lower values. Manual selection from the 0.25-m² samples produced still lower values. Visual evaluation in autumn showed the Enchytreidae to be the most numerous.

Note: Comma represents decimal point.

took part. This gives a difference of 172.5 g or 50.8% of the quantity of leaves remaining after decomposition without participation by invertebrates. In the second series the difference was 228.4 g (470.1 less 241.7) or 48.6% of 470.1 g. The difference figures (50.8% and 48.6%) are therefore fairly close.

The fact that the condition of the control litter in regard to degree of decomposition in the second series of experiments (where the litter was caked and intact) and in the surrounding parts of the forest indicates that the natural course of decomposition was not affected by the presence of the frames over the leaf fall.

From the experimental values it can be inferred that the decomposition of oak litter by bacteria and fungi alone is slow. These values bear out the propositions that soil animals accelerate the decay of plant residues by breaking them down, partially digesting them, adding them into the soil along with excrements and bacteria and so forth (2, 4, 5, 8, 10, 16, 17). The microorganisms in turn promote the activity of soil saprophages; invertebrates are reluctant to eat fresh litter which has not been subjected to any microbiological decomposition at all; conversely the more the litter has been worked over by microorganisms, the more intensively it is consumed by animals (17, 19, 21). It follows that the activity of microorganisms in the process of plant residue decay is associated with that of invertebrates.

Among the larger soil invertebrates the main agents of oak litter decomposition in the Central Chernozem Reservation are the rain worms *Dendrobaena octaedra* Sav., the Enchytreidae, the thread polypods (*Sarmatiulus kessleri* Lohm,

Chromatoinlus rossicus Tim., *Brachyiulus jawlowski* Lohm.), the wood louse *Tracheoniscus rathkei* Brandt and the larvae of the leatherjacket *Tipula scripta* Meig.

The laboratory tests showed that the daily consumption of oak leaf litter (converted to dry weight) per day was: by older *Tipula scripta* larvae (pre-experiment weight 136-191 mg), 10-15 mg; adult *Sarmatiulus kessleri* (weight 202-245 mg), 10-11 mg; adult *Tracheoniscus rathkei* (weight 43-45 mg), 2-3 mg; animals with a heavier body weight per unit mass consumed less food.

The count of litter population (Table 2) showed an average of approximately two leatherjacket larvae, three thread polypods and seven wood lice per m² over the two months from the end of May to the end of July. Calculations made on the basis of the amount of litter consumed showed that in the two summer months alone these animals could destroy at least 5 g of oak litter (converted to dry weight) per m² of forest.

The population in those species of invertebrates with which the laboratory experiments were concerned was low; these species, therefore, had no major importance in the decomposition of the oak litter in the reservation, where the main role was played by the rain worms *Dendrobaena octaedra* (up to 170 per m² of litter), the Enchytreidae (up to 2570), the ticks (up to 22,380),³ and the collembola (up to 6110). These

³According to determinations made by Yu. V. Byzovaya, who studied soil ticks in the Central

values are an underestimate as a result of imperfections in the counting methods used, which did not allow all the animals encountered in the soil and litter to be taken into account. In addition to the animals enumerated, land molluscs, nematodes and other decomposition agents not counted by us also took part in the decomposition of the oak litter. The combined activity of all invertebrates together with bacteria and fungi had a similarly important effect in the experiments described.

Weather conditions promoted decay of the litter. In summer and autumn of 1958, there were comparatively few days when the litter was completely dried, with the result that the animals left the litter layer and returned to the soil. Fairly low temperatures, frequent and fairly abundant rainfall and morning dews in the intervals between showers kept the litter damp over a long period. Only in the period from late May to the beginning of June and at the beginning of the second half of July was the weather dry and warm; the invertebrates then stayed in the litter (Table 2). On May 31 and June 1, for example, despite the increased population (as a result of spring growth) the count for nearly all the animals was lower than in the preceding count (May 21-22). This was particularly striking in the case of the rain worms: in 10 days (June 10-21) when there was continuous rain and constant temperatures, the number of rain worms in the litter sharply increased. On July 20-21, after a long break in the rainfall and relatively high temperatures rising from day to day, the number of rain worms in the litter again sharply declined. The maximum quantity of rain worms was observed in the first 10 days of July, whereas the maximum quantity of nearly all the other larger animals responsible for litter decay was observed in the last 10 days of June. It must be noted that in 1958 the development of the invertebrates was very late (the *Tipula scripta* Meig larvae, for example, are according to Savchenko (11) usually found from early spring until the beginning of June).

Among the small arthropoda, the maximum tick population was observed at the beginning of the second 10 days in June and the maximum collembola population at the beginning of the last

10 days of that month (Table 3).

Role of Invertebrates in the Humification of Oak Litter

Soil invertebrates play not only an indirect but also a direct role in the decomposition of organic matter. "In the process of animal metabolism complex organic substances and organic residues are broken down. Some representatives of the soil fauna are capable of hydrolyzing not only the readily absorbed carbohydrates, fats and proteins, but also much more resistant substances like cellulose, keratin and chitin. As a result of metabolism various organic substances are converted into plant-available compounds (carbon dioxide, water, ammonia) or readily mineralized compounds (urea, uric and hippuric acids, guanine). Many salts are also excreted in the free state—the chlorides and phosphates of potassium, magnesium, sodium, calcium, etc."(4) In addition, humic substances, the importance of which is well known, are formed in the digestive processes of soil animals.

Franz and Leitenberger (20), who set up specific tests to investigate the excrements of a series of soil invertebrates, confirm that a humus-like substance, which they believe to be a first stage in humus formation, is formed intestinally directly from fresh litter that has not yet been subject to microbiological decomposition. These investigators determined the degree of humification from the quantity of acetyl bromide-insoluble matter, using the colorimetric method, comparing the excrements with the original food. They believe that in the process of digestion a humic substance is synthesized, a substance which is insoluble in acetyl bromide being converted into one which is soluble. Quoting other investigators, they state that even animals which feed on green vegetation are capable of producing humic substances.

These inferences are borne out by the findings of Dunger (18), who studied how the litter changes in the intestine of certain species of polypods and wood lice, by spectrophotometry of an alkaline (NaOH) extract from the excrements. Dunger chose groups of animals, Diplopoda and Isopoda, which were not suitable enough to settle the question of humus formation. By means of detailed histological investigations he found that animals belonging to these groups do not easily digest plant tissues. Our own investigations provided further evidence of this. Van der Drift and Kubiya (quoted by Franz (19) also noted that

Table 3

Tick and collembola population in oak forest litter in the Central Chernozem Reservation in 1958 (thousands per m²)

Animals	22.V	1.VI	11.VI	22.VI	3.VII	12.VII	21.VII	1.X
Ticks	16,08	19,29	22,38	20,37	18,70	13,60	8,56	14,95
Collembola	3,27	4,21	4,11	6,11	4,32	4,55	2,28	4,86

Note: Comma represents decimal point.

digestion of plant material by the polypods *Diplopoda* and the wood lice was incomplete. It is therefore not surprising that Dunger detected only a slight increase in the amount of humic acids in the excrement of the animals he studied as compared with the food consumed.

What is this first stage in humus formation referred to by Franz and Leitenberger? It may possibly consist of those amorphous brown humic substances produced by Kononova (8) in experiments on the decomposition of alfalfa roots by microorganisms and larvae of the fly *Sciara* sp. which he calls "prehumic."

When the extracts we obtained from the initial material (litter which had been subjected to microbiological action), using sodium fluoride, were compared with the excrements of *Sarmatiulus kessleri*, *Tracheoniscus rathkei* and *Tipula scripta*, it was found that humic matter formation in the thread polypod and wood louse intestines was poor. The color of the excrement extracts was almost as bright as that of the original leaves. The extract from the excrements of leatherjacket larvae was distinguished by a much darker color.

What has been said previously about the role of soil animals in humus formation does not contradict the experimental finding that the humic matter content in the excrements of thread polypods and wood lice is not greater than that in the litter. This explanation is: first, that the food taken in by these animals is incompletely digested; and secondly, that of all tree species, except the beech, the oak produces the least digestible leaf for litter saprophages, including the thread polypods and wood lice and even, as Dunger confirms (17), for microorganisms. Oak leaves are less readily consumed by all animals and produce a much smaller quantity of new humus in the excrement than do other more easily broken down leaves such as those of the alder, ash, basswood and other trees (17, 19). Two examples may be adduced in support of this: 1) according to investigations by Volz (22), in Germany, alder forest litter completely disappears as early as the end of April, whereas in oak-ash forests the oak leaves decay as a rule during the 12 months following the defoliation period and the ash leaves decay a good deal earlier. 2) in the experiments by Franz and Leitenberger (20) mentioned previously, the excrements of the earthworm *Lumbricus rubellus* Hoffm., fed on oak leaf fall contained only half as much newly formed humic matter as that of the same animals fed on black alder leaves and only one-third as much as that of those fed on hazelnut leaves.

Dunger (18) fed polypods and wood lice, through the winter, oak leaves and established that there was a slight reduction in the amount of humic matter in the excrement of the first and a very slight increase in that of the second in comparison with the original material. It can therefore be said that thread polypods and wood lice do not themselves create humic substances in the course of oak litter decomposition and play only an indirect part in humus formation in the oak stands of the reservation, if we do not consider the possibility of their forming these substances from the litter from

herbaceous plants and other tree species and shrubs typical of the oak stand.

The picture is different in the case of *Tipula scripta* larvae. Here the excrements understandably show a substantial increase in the amount of humic matter, since these belong to a group of insects which are capable of digesting cellulose (2, 3). Unlike the thread polypods and wood lice, in which the intestine is in the shape of a straight tube, these animals possess a digestive system of peculiarly complex arrangement. In addition to other complications of the digestive system, larvae which break down cellulose have an extremely dilated posterior intestine (the *Lamellicornia*), or even a peculiar and relatively extensive excrescence at the beginning of the posterior intestine (*Tipula*) forming a so-called "zymotic camera" in which, as it would seem from Werner's findings quoted by Gilyarov (3), cellulose is broken down with the help of microorganisms. The activity of these microorganisms is undoubtedly connected with the animals' digestive processes. Microorganisms are active in the animals' intestines and depend on the latter's vital activity. The formation of humic substances occurs as a result of the combined activity of invertebrates and microorganisms. Leatherjacket larvae accordingly themselves take part in creating humic substances even in connection with the decomposition of oak litter.

V. V. Ponomareva analyzed the excrements of thread polypods, wood lice and leatherjacket larvae collected by us. The method used, however, did not make it possible to find the difference in the humic matter content in the leatherjacket larvae excrements as compared with those of the thread polypods and wood lice. The qualitative composition of the organic matter in the excrement was very similar to that in the original oak leaves (from the forest litter).

From this it may be concluded that different animals produce humic substances in different amounts, depending on the type of food they eat.

An immense amount of excrement falls into the soil. It is known from the foreign literature cited by Franz and Leitenberger (20) that the upper layer of many forest soils has an exclusively coprogenic character. This layer is continuously built up from above and drawn down into the soil from below.

Organic residues falling into the soil in the form of excrement after primary processing by invertebrates and intermingled with mineral particles is subjected repeatedly to the action of microorganisms and repeatedly passes through the intestines of various animals (coprophages and saprophages), with the result that one way or another the organic material alters, in the direction of humification.

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ROLE OF INVERTEBRATES IN THE NATURAL DESTRUCTION OF OAK WOOD

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The main sources of organic soil matter under forest conditions are the forest litter and rotting wood. The rate and nature of the destruction of these plant residues has a decisive influence on the fertility of the soil. Fungi, bacteria and invertebrate animals play the main part in their decomposition (5). These three groups of organisms are closely interrelated in regard to their activity, but we should recall that the part played by invertebrates in bringing about the humification of wood and forest litter consists, first, in breaking down these plant residues, thereby creating particularly favorable conditions for the growth of fungi and bacteria, secondly, in the chemical action of the digestive juices in their intestinal tract on that part of the organic substrate which they use as food, and thirdly, in transferring the broken down plant residues from the soil, in enriching them with microdic flora and so forth.

The part played by invertebrates in the natural destruction of plant residues has therefore so many aspects that an evaluation such as we have made by taking the destruction of oak wood as an example presupposes, on the one hand, quantitative counts of the invertebrate population under natural conditions, and, on the other hand, laboratory experiments and chemical analysis.

Material and methods

A count of the main agents of oak wood destruction and experiments to discover the rate at which they digested the wood were made in the Tula abatis and the Tellerman forest (Voronezh region). To determine the population in invertebrate species occurring in large numbers a manual selection was made of wood from individual stumps or populated sections of the trunks and the population in the given species per cm³ was counted. The digestion rate of the wood by the invertebrates was determined by rearing 5-10 larvae of a particular species for 5-15 days in small blocks

of the wood at the same stage of destruction as the species under investigation prefers in nature. This digestion rate was expressed in terms of cm³ of wood digested by one adult larva per day.

The material for evaluating the chemical changes in the digested wood by particular species of invertebrates was collected under natural conditions. The composition of the walls of the wood forming the passages (initial material) and of the excrements filling the passages (digested wood) was compared. For the purposes of the analysis, wood and excrement were taken only from parts with freshly laid down passages. Although it was impossible to exclude completely the action of fungi and bacteria on the digested wood, the time during which such action took place was small and it may therefore be taken that fungi and bacteria could not have caused any substantial changes in the chemical composition of the wood under investigation.

Succession of Invertebrate Destroyers of Oak Wood

As the wood rots, its strength, structure and composition undergo serious changes. As a result, the invertebrate species which originally inhabited the wood are no longer adapted to such environment at the later stages of decay and therefore give place to new species. This means that any given combination of invertebrate species is as a rule associated with a particular stage in the destruction of the wood, so that the condition of the wood (i. e., the stage of its destruction) can be assessed from the species composition of its invertebrate population.

In order to assess the role of particular groups of invertebrates in causing humification of the wood, it is convenient to separate the destruction process into four stages: destruction by Cerambycidae, Lucanidae, Formicidae and Lumbricidae, respectively (3). The basis for this division is developed from the data collected by us in the central belt of the European part of the USSR. The groups which successively occur in large numbers in wood of various types, according to the degree to which it has been destroyed, are the larvae of the long-horned beetle (Cerambycidae), the larvae of the stag beetle

¹The zoological part of the work was done by B. M. Mamayev and the biochemical part by D. F. Sokolov.

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(Lucanidae), ants (Formicidae) and rain worms (Lumbricidae); the latter are found in combination with other soil invertebrates such as the diplopodous polypody, wood lice, Enchytreidae and so forth. The horn tail (Siricidae) and burncow (Buprestidae) larvae, which inhabit the wood at the same time as the long-horned beetle larvae and are characteristic of the Cerambycidae stage of destruction, are less common and are connected mainly with trees of the coniferous orders.

This succession of representatives of the main groups of xylophages and xylophilous invertebrates is confirmed by fauna lists published in connection with the study of the animal succession in wood (8, 17, 21). At the same time, the species composition of each group of invertebrates at a given stage of destruction of the wood depends on a great variety of environmental conditions, especially climatic, and the type of destruction caused by fungi. This can be demonstrated from the example of the destruction of oak wood in the Tula abatis and Tellerman forest (Table 1).

The oak wood in the compartments (41, 47, 34, and 56) investigated in the Krapivenskoye forestry of the Tula abatis are destroyed primarily by fungi-Polyporus sulphureus and Daedalea quercina - which cause a characteristic destructive brown rot of the heartwood while the drier sapwood is not affected and retains its light color.

During the first (Cerambycidae) stage of wood destruction the sapwood of the oak stumps was found to be populated by the oak pruner larva Leptura sexguttata F. (of the long-horned beetle) and the larva Hypulus quercinus Quens. The larvae of the latter species are particularly numerous, occurring in large conglomerations of up to 150 larvae per cm² of wood. These convert 13.5% of the sapwood into rotten wood. The larvae Leptura sexguttata F. and Hypulus quercinus Quens, however, do not inhabit the heartwood, which in this first period is destroyed solely by fungi.

In the second (Lucanidae) stage the wood destroyers are the larvae of the stag beetle (Cerambycus chrysomelinus Hochw.) and of dip-

tera belonging to the family Lycoriidae, which are found in large colonies. At this stage the click beetle larva Melanotus rufipes Hbst. and other Elater spp. play an important part in the mechanical destruction of the oak wood.

The large C. chrysomelinus larvae settle the entire thickness of the heartwood, which by now is becoming reddish-brown in color. The mean larva population density is 4.7 per cm³ and the maximum density 8 per cm³. The C. chrysomelinus larvae turn up to 50% of the oakwood into rotten matter, 13%-15% of which consists of their excrements. The mean digestion rate by these larvae in the adult stage is 0.45 cm³ per day. In the Tula abatis the larvae of this species are the main oak wood destroyers; in those forest compartments where, for one reason or another, they do not occur, the destruction of the oak wood proceeds a good deal more slowly.

The third (Formicidae) stage of oak wood destruction is caused by ants, mainly Lasius niger L., L. fulliginosus Latr., Myrmica ruginodis Nyl., more rarely L. mixtus Nyl. and others. Large nests are found in the wood only in warm sunny parts of the forest.

In the Tula abatis, stage 4 (Lumbricidae) is caused mainly by the diplopodous polypody, Proteroinulus fuscus am St., Schizophyllum subulosum Verh., Polydesmus complanatus L., P. denticulatus C. L. K. and others (determined by I. Ye. Lokshina). It should be noted that the invertebrates found during the last two stages of the wood destruction are characteristic inhabitants also of the forest litter and soil and so play an important part in the transformation of the organic matter under the forest stands (4). Humification of the oak wood is completed by the rain worm Bimastus tenuis Eisen.

The oak wood in compartments 51 and 52 of the Tellerman forest is destroyed by fungi, which cause a white rot (for example, Fomes fomentarius and others) and this is one of the main reasons why the oak fauna in the Tellerman forest is different from that in the Tula abatis. In the Tellerman forest the main agents destroying the sapwood of oak stumps are

Table 1
Succession of invertebrate destroyers of oak wood

Locality	Tula abatis	Tellerman forest
Stage of destruction	Brown rot	White rot
Cerambycidae	<u>Leptura sexguttata F.</u> , <u>Hypulus quercinus Quens.</u>	<u>Strangalia sp.</u> , <u>Xestobium rufo-villosum</u> De Geer
Lucanidae	<u>Cerambycus chrysomelinus</u> Hochw.	<u>Dorcus parallelipedus L.</u> , <u>Lucanus cervus L.</u>
Formicidae	<u>Lasius niger L.</u> , <u>Myrmica ruginodis Nyl.</u>	<u>Lasius niger L.</u>
Lumbricidae	<u>Bimastus tenuis</u> Eisen., <u>Proteroiulus fuscus</u> am St., <u>Polydesmus complanatus L.</u>	<u>Eisenia foetida</u> Sav.

the larvae of the furniture beetle, *Xestosium rufovillosum* de Geer. These are fairly numerous (up to 50 per cm³) and convert up to 50% of the sapwood into excrement. The larva *Hypulus quercinus* is not nearly so common. The heartwood is destroyed by the horned beetle larva *Stangalia* (*quadrifasciata* L. ?); there is rarely more than one of these larvae per cm³ of wood. In the Lucanidae stage three species of stag beetle destroy oak stumps and slash: *Dorcus parallelipedus* L., *Lucanus cervus* L. and *Sinodendron cylindricum* L. The first of these species is extremely numerous, occupying nearly all the stumps and trunks of oak and other tree species in which the wood has reached a condition favorable for the growth of its larvae. The second species destroys the roots of oak stumps; the third is found comparatively rarely in oak wood and does not play an important part in its destruction.

The stag beetle larva population averages 3.5 per cm³ of wood. These larvae digest up to 40% of the wood into rotten matter, using about half of this amount as food. The rate of wood conversion by these larvae is 2.2 cm³ per day. In the Tellerman forest the species is the main oak wood destroyer.

Other larvae which are active in destroying oak wood during the Lucanidae stage are those of the leatherjacket, *Dictinidia bimaculata* L., the Alleculidae, *Prionychus ater* F. and often the darkling beetle, *Uloa culinaris* L. The Formicidae stage of oak wood destruction is effected by the ants *Lasius niger* L. and *L. nylanderi* Först and others which, however, by no means always inhabit the wood. In the Tellerman forest the Lumbriidae stage of oak wood destruction is connected with infestation by Enchytraeidae and the large rain worms *Eisenia foetida* Sav. in the rotten wood and old passages made by the stag beetle. *Bimastus tenuis* is found far less frequently. The rotten wood is repeatedly subject to the action of rain worms and during migration times is partially carried out of the stump into the surrounding layers of the soil by the worms.

Both in the Tula abatis and in the Tellerman forest, then, oak wood destruction is effected mainly by the larvae of stag beetle during the second (Lucanidae) stage. In the concluding stages of humification of the wood, rain worms and diplopod polypods play an active part.

Wood Decomposition in the Intestines of Invertebrates

Invertebrates use as food the wood which they have digested. Mechanical destruction is, therefore, followed by the action of intestinal enzymes on the wood.

Papers on the physiology of invertebrate xylophage digestion relate mainly to the larvae of insects inhabiting the wood during the early stages of its destruction (15, 18). Deschamps (9) has given a detailed review of the results of research in this direction.

Comparison of the information obtained mainly by these authors (Table 2) establishes that the larvae of insects inhabiting the wood

during the Cerambycidae stage of its destruction possess the most complete range of enzymes and can hydrolyze and absorb such relatively resistant substances as cellulose and hemicellulose. Buchner (6) associates the secretion of certain intestinal enzymes, primarily cellulase, with the activity of intracellular intestinal symbionts which multiply in the mycetoma of the intestinal wall. It has been suggested, however, in a number of later papers (12, 18) that the cellulase is secreted indirectly by the glandular cells of the intestinal epithelium.

The appearance in the wood of the larvae of the leaf-horned beetle (*Lamellicornia*) marks the beginning of the Lucanidae stage of destruction. These larvae apparently obtain their food from the products obtained from wood hydrolysis under the influence of enzymes excreted by the intestinal microorganisms (20) and also by digesting the bodies of these microorganisms themselves, which multiply abundantly in the larva intestine (22). However, this may be, it has not been possible to detect any cellulose- or hemicellulose-hydrolyzing enzymes in the intestines of these larvae (18).

It appears, then, from this brief review of the literature on the digestive physiology of xylophagous insect larvae, that as a rule they possess the necessary set of intestinal enzymes to bring about certain changes in the chemical composition of the wood they use for food, by hydrolyzing all its components except lignin. The literature contains comparatively little information about the range of enzymes possessed by invertebrates outside the insect class. Cellulase, for example, has been detected in xylophagous molluscs (the ship worm [Dore and Miller, quoted in 16]), in the rain worms (19) and apparently also exists in the diplopod polypods and wood lice.

Papers (7, 16, 10, 14 and 11), which give the results of comparative chemical analysis of wood before and after it has been digested by insect larvae, are of great interest. These results indicate that the larvae of the main insect species which destroy wood hydrolyze 20%-50% of the cellulose and 13%-30% of the hemicellulose in the process of digestion.

Since the stag beetle larvae play the main part in the natural destruction of oak wood, particular attention has been devoted to these larvae in the study of wood destruction chemistry. Comparative biochemical analysis has been made of the original wood and the excrements of *Ceruchus crysomelinus*, *Dorcus parallelipedus* and *Lucanus cervus*. Larvae of the latter species digest the wood repeatedly, feeding on a peculiar compost which they prepare by first pulverizing the wood.

The analysis results (Table 3) show that the part played by invertebrates in the course of natural destruction of wood is associated with noteworthy changes in its chemical composition. The increased ash element content in the digested wood indicates that a certain amount of the organic matter, proportional to that increase, is used by the invertebrates. The total decline in the organic matter content is due, in the first place, to the invertebrate demand for substances soluble in water and in alcohol-benzonol

Table 2
Composition of digestive enzymes in xylophagous insects (12, 14, 11, 15, 18)

Substance investigated	Pro- tease	Amy- lase	Lichen- ase	Cellu- lase
1. Ipidae (<i>Phloeosinus bicolor</i> , <i>Hylesinus fraxini</i>)	+	+	+	-
2. Cerambycidae (<i>Acanthocinus aedilis</i> , <i>Cerambyx cerdo</i> , <i>Ergates faber</i> , <i>Hylotrupes baiulus</i> , <i>Isotomus speciosus</i> , <i>Oxyrinus cursor</i> , <i>Phymatodes testaceus</i> , <i>Plagionotus detritus</i> , <i>Rhagium</i> spp., <i>Stromatium fulvum</i> and other).	+	+	+	+
3. Buprestidae (<i>Chalcophora mariana</i>)	+	+	+	+
4. Anobiidae (<i>Anobium punctatum</i> , <i>Xestobium rufovillosum</i> , <i>Ernobius mollis</i> , <i>Ptilinus pectinicornis</i>)	+	+	+	-
5. Lamellicornia (<i>Cetonia aurata</i> , <i>Potosia cuprea</i> , <i>Dorcus parallelipedus</i>)	+	+	-	-

Table 3

Changes in the chemical composition of oak wood after it has been digested by invertebrate animals^a

Wood components	White rot									Brown rot			Rotted material					
	Xestobium rufovillosum			Hypulus quercinus			Dorcus parallelipedus			Lucanus cervus ^c			Cerychus chrysomelinus			Bimastus tentis		
	A ^b	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Organic (ash free) sub- stances soluble in boil- ing water	12.85	12.98	101.0	8.40	10.80	128.6	12.26	9.12	74.4	5.64	6.12	108.5	10.14	7.45	73.4	4.78	4.88	102.0
Organic substances solu- ble in alcohol-benzonol (1:1)	2.54	3.04	119.6	2.43	2.24	92.2	1.92	0.93	48.4	1.27	2.08	163.8	7.50	4.52	60.2	2.40	1.41	60.0
Hemicellulose	15.56	14.56	93.6	15.27	16.20	106.1	18.33	16.86	92.0	17.58	12.94	73.6	1.46	2.42	165.7	10.83	9.16	81.6
Cellulose	37.43	31.03	83.5	39.97	36.23	90.6	22.98	26.55	115.5	27.93	24.74	88.6	15.90	10.61	66.7	14.88	15.71	105.5
Lignin residue	21.29	26.31	123.6	19.08	20.59	107.9	26.15	27.51	105.2	28.23	29.59	104.8	50.30	63.48	126.2	42.21	40.63	96.2
Nitro. subst. (N x 6.25)	4.54	2.25	146.1	2.08	2.93	140.8	2.09	3.28	156.9	2.73	2.69	98.5	2.69	2.77	102.9	2.90	3.87	133.1
Ash elements	4.24	4.51	121.8	4.01	4.91	189.4	3.84	5.63	146.6	3.36	14.29	425.3	1.19	4.27	106.7	4.98	11.61	233.1
Total	92.15	91.68	99.5	88.24	90.90	103.0	87.57	89.88	102.6	86.74	92.45	106.6	89.18	92.52	103.7	82.98	87.36	105.2

^aThe N. P. Bel'chikova working method was used for the biochemical analysis (2); protein nitrogen was determined by the Barnstein method (1).^bA - Content in original material; B - Content in material digested by animals; C - B as a percentage of A.^cWood subjected to repeated digestion by invertebrates.

Note: Comma represents decimal point.

and also to the demand for hemicellulose and cellulose. The relative amount of lignin, however, noticeably increases, especially when lignin-rich brown rot has been digested.

One would hardly expect radical changes in the chemical composition of wood after a single digestion by invertebrate animals. Nevertheless, comparison of the values for the invertebrate population under natural conditions, the rate at which they digest the wood, and the chemical analysis values indicate that invertebrates are of serious importance both in the mechanical pulverization of wood and also in those chemical changes which in the last analysis lead to the conversion of a certain part of the wood into organic soil matter while another part is broken down into very simple mineral compounds CO_2 , NH_3 , H_2O and others.

Conclusions

1. In the Tula abatis the main role in oak wood destruction (brown rot) at various stages is played by *Hypulus quercinus* Quens., *Ceruchus chrysomelinus* Hochw., *Proteroiulus fuscus* am St., *Polydesmus complanatus* L. and *Bimastus tenuis* Eisen. White oak rot in the Tellerman forest, Voronezh region, is caused by *Xestobium rufovillosum* de Geer, *Dorcus parallelipipedus* L., *Lucanus cervus* L. and *Eisenia foetida* Sav.

2. Xylophagous invertebrates use mainly those substances in the wood which are soluble in water and alcohol-benzonol, namely the hemicellulose and cellulose. The relative amount of lignin in the digested wood increases.

3. The role of invertebrates in destroying wood consists mainly in mechanically breaking it down and partly in chemical hydrolysis. The large numbers of several species of xylophage invertebrates indicates that the activity of these animals is of major importance for the circulation of substances under forest conditions.

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CHANGES IN THE PHYSICAL PROPERTIES OF YERGENI SOLONETZES UNDER THE INFLUENCE OF SHRUBS

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In 1950, an experiment was inaugurated by the Stalingrad joint expedition near the Tinguta station, on the melioration of solonetztes by the application of gypsum and by the biological method of planting shrubs.

The present article contains information describing the changes that occurred under the influence of the shrubs in certain properties of the solonetztes that had not been treated with gypsum. In this experiment, described in our other paper (3), the meliorating action of *Tamarix*, *sumac* (*Cotinus*), *Elaeagnus*, the yellow acacia and the Tatar maple and box-elder was studied. The shrubs were planted in 1952. From 1953 to 1958 we made observations on the growth and development of the shrubs and the soil processes. Little work has been done on the possible use of shrubs as meliorators. Many investigators note the improvement in soil properties under the influence of woody vegetation (12, 8, 7 and others) and the use of tree stands in melioration for bio-drainage purposes (1) but very little research has been done on the meliorating effect of shrubs on the soil (5, 3, 4). In India, the use of shrubs from among the legumes *Crotalaria anagyroides*, for meliorating the surface layer of the atmosphere and the soil, is fairly widespread.

The biomeliorating action of shrubs on the soil is many-sided. It chiefly takes the form of increasing the biological activity of the soil and its mechanical loosening. Microbes in the rhizosphere of the roots and the root excretions enrich the soil in organic matter and carbon dioxide, promoting the conversion of carbonates into bicarbonates. The leaf fall is rich in calcium and returns nutrients to the soil. All these processes in combination lead to the desolonetzation of the soil and increase its fertility, as was demonstrated by Vadyunina and Verevkina (4).

The mechanical effect of shrub roots in separating and loosening the soil mass is also of great importance. Many shrubs possess a thick root system, which is stronger than the perennial grasses used in solonetz melioration.

A study of the root systems in the shrubs used in the experimental plantings showed that the roots were distributed in the soil profile in two stories (Fig. 1 and 2). The first story comprises mainly the humic horizons, which

vary in thickness from 0-60 or 0-30 cm depending on the shrub species. Most of the roots are concentrated in this layer. A second story is distributed beneath solonetzic saline horizons. The density of roots in the soil and the depth to which they penetrate are determined by the biological characteristics of the shrubs. We shall describe the root distribution of two shrubs, the *Tamarix* with its thick root system and the box-elder (*A. negundo*), which has a poorly developed root system. The roots were uncovered in solonetz soil in plantings of the fifth experimental plot. The root system was better developed in the 3-year-old *Tamarix* than in the 5-year-old box-elder. The *Tamarix* is salt-tolerant. Its roots penetrate deep, passing through the saline horizons. The box-elder appears to be sensitive to any increase in the amount of readily-soluble salts contained in the soil and its roots are concentrated mainly in the plowed layer; they either never reach the sub-solonetz horizons (Fig. 2) or, if they do, become weak and poorly developed there. Owing to the intensive drying-out of the soil, the top 10-cm layer contains hardly any roots. Ephemeral roots appear in it during a wet period but die when the soil dries out.

In the 3-year-old *Tamarix* the lateral root branches, which spread horizontally, are up to 380-cm long. Vertical secondary root branches penetrate to a depth of 155 cm. Roots of the second and third order vary in thickness from 0.3-1.0 cm or more. A thin network of suctorial roots is formed.

The box-elder has a thick main root from which small, thin roots 40-60 cm long branch off horizontally and vertically to a depth of 15 cm. In the vertical direction the roots branch mainly from the main root, not from the secondary ones as in the case of the *Tamarix*. They lie mainly in the plowed layer and only occasionally enter the B_1 horizon.

A schematic count showed that the volume of soil covered by the shrubs under consideration is 2.8 m³ in the case of the *Tamarix* and 1.4 m³ in the case of the box-elder. Shrubs with a thick root system are more effective in solonetz melioration as we will show below; those with weakly developed root systems die in solonetztes.

The solonetztes in the Yergeni soil complex occupy from 10% to between 50% and 70% of the

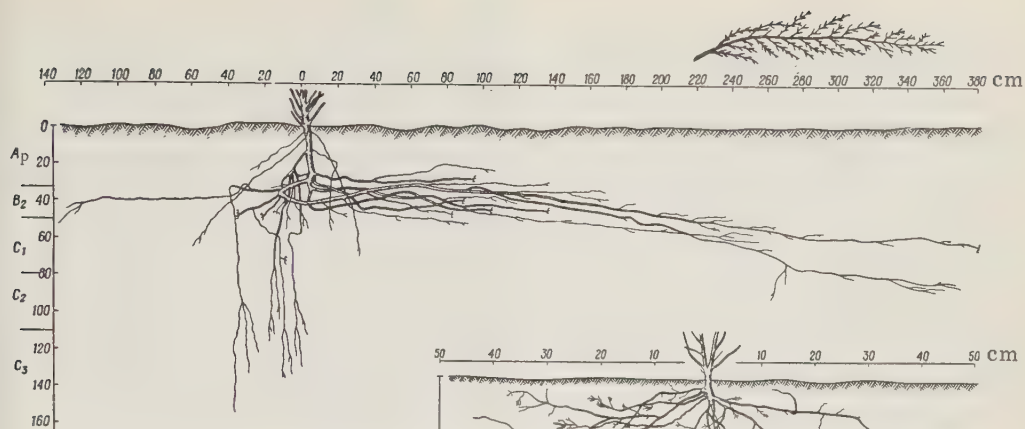


Fig. 1. - Root system of 3-year-old Tamarix in solonetz.

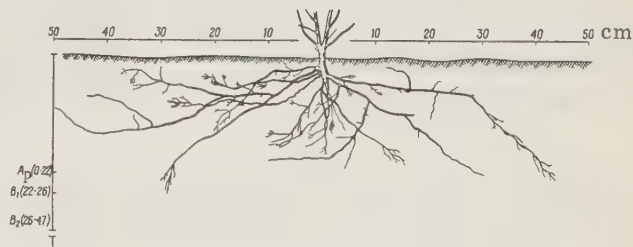


Fig. 2. - Root system of 5-year-old box-elder.

total area and are represented mainly by medium-columnar and crustal fine clay-loam types.

The adsorbed sodium-content in the solonetzses is not high. Processing the data obtained from our own analyses and those available in the literature we find that the average content of 10 analyses shows that sodium accounts for 4%-9% of the total adsorbed bases in the 10 cm layer, 17.7% in the 10-20 cm layer and up to 23.5% in the 20-30 cm layer (Table 1).

In agreement with Orlovski (11) and Ratner (12) such quantities of sodium are not toxic.

If we adopt the classification of the Yergeni solonetzic soils suggested by Kachinskiy (9), and so classify the soils in which sodium accounts for more than 15% of the total adsorbed bases among the solonetzses, the soils under study belong to the group of weakly and medium solonetzic soils in the 10 cm layer and to the strongly solonetzic or, more rarely, the solonetzses in the 10-20 cm layer (the B₁ horizon). With so low a sodium adsorption, however, solonetz melioration must take the form of displacing the sodium by calcium.

Table 1

Sodium as percentage of total adsorbed bases

Depth, cm	Range in content	Average content
0-10	1.0-11.3	4.9
10-20	12.0-24.0	17.7
20-30	--	23.5

In the virgin solonetzses studied, the amount of readily soluble salts increases sharply as one passes from the A to the B₁ and lower horizons. In the first two horizons the residue of water extract varies from 0.07%-0.3%; in the sub-solonetzic horizons and below it reaches 0.7% to 1.5%-2.0%.

The total salt contents, in metric tons per hectare (Table 2), calculated on the basis of the compact water extract residue for various depths and summed by meters, are 113.7 in the first meter, 246.9 in the second meter and 242 in the third meter. Total salts in the root layer (0-2 m) amount to 360.7 metric tons. With a bulk density averaging 1.45 g/cc in the first meter and 1.55 g/cc in the second meter, the weight of the first meter of soil is 14,500 metric tons/ha and of the second, 15,500 metric tons/ha. If we take the toxicity of the residue of water extract layer as 0.3%, the critical salt amount in the first meter will be 43.5 metric tons/ha and in the second, 45.5 metric tons/ha, or 89 metric tons/ha in the 2 m layer as a whole.

This means that in order to reduce the salt content in the solonetz to the acceptable standard for plants, about 170 metric tons of salt per hectare will have to be removed from the 2m layer, either by forcing it down to a lower depth or by flushing it into a drainage network. The desalinization of solonetzses, moreover, is one of the main conditions for their desolonetzation.

As can be seen from Table 2, which shows the total salt content in solonetz under 3 and 6 year Tamarix, desalinization of the soil profile takes place under the influence of these shrubs. The desalinization is stronger in the rows of shrubs.

Table 2

Water-soluble salts in virgin solonetz and solonetz under Tamarix (metric tons/ha)

Depth, cm	Virgin soil	Tamarix	
	1955	1955	1958
0—50	26,2	14,2	10,4
50—100	93,2	23,8	12,7
100—150	137,7	110,7	96,0
150—200	112,3	150,0	128,0
250—300	121,0 ^a	—	160,0

^aThis value is taken from the analytical for 1952.

Note: Comma represents decimal point.

barley develop a weak root system in solonetzic spots. A thick compact crust forms on tilled solonetztes after wetting, preventing the plants from germinating. The high density and low water permeability of the solonetztes makes it difficult to desalinize the soil profile by natural or artificial irrigation. Improvement of the physical properties of these soils is, therefore, one of the main tasks in meliorating them. Combined study of the properties of solonetztes in virgin land, plowed areas and areas under shrubs has revealed substantial improvement in the physical structure of the soil profile under shrubs. The density of solonetztes is expressed by the specific gravity of the soil (d_v) or its bulk density expressed in g per cm³. We determined this value with Kachinskiy's instrument, measuring five times to a depth of 20 cm and three times below this depth. All the d_v and particle density, d

Table 3

Adsorbed sodium content in virgin solonetz and solonetz under 7-year-old shrubs (meq per 100 g of soil)

Depth, cm	Tinguta, experimental plot No. 5.				Stalingrad, experimental Plot. No. 3		
	Virgin soil	Yellow acacia	Elaeagnus	Sumac	Depth, cm	Virgin soil	Elaeagnus
0—10	1,93	1,84	1,37	1,09	0—10	1,59	1,59
10—20	—	2,03	1,06	—	12—22	5,05	2,68
20—30	4,33	3,86	3,67	2,52	31—37	—	3,53

Note: Comma represents decimal point.

Under the influence of the decomposition products of the litter rich in calcium and of dying roots, as well as of the secretions of living roots, the amount of adsorbed sodium in the soils under shrubs decreases (Table 3). This is a major factor in improving the physical properties of the solonetztes. It must be noted that the litter of Tamarix assimilation twigs with a high sodium sulfate content produces solonetzization and salinization of the top-soil (0-10 cm) (4).

Physical Properties of Solonetztes and their Modification Under Shrubs

Antipov-Karatayev (2) believes that in solonetztes with a high chloride-sulfate content the unfavorable physical properties of these soils are a factor in limiting yields. The physical and water properties of soils usually start to deteriorate when the adsorbed sodium content is 10%-20% of adsorption capacity. The unfavorable physical properties of the Yergeni solonetztes are probably due to their having contained a large amount of adsorbed sodium in the past and must be classed as a relict phenomenon.

The solonetztes have a very compact, hard B₁ horizon, which exerts a strong mechanical resistance to the developing of root systems of plants, especially cultivated crops. Wheat and

(numbering n^1), as determined along the profile over a 5-year period, were averaged to give a mean value, M , a mean square-root deviation m , and an experimental error value, P . The total number of treatments obtained was equal to the product of N and the number of times the determinations were made: for the upper layers, $n \times 5$ and for the lower layers $n \times 3$.

The bulk density of the virgin solonetz (Table 4) was fairly high and varied in the 2 m layer between 1.37 and 1.54, the lowest value being in the A horizon and the highest in the illuvial horizons (the carbonate and gypsum B₁). The reliability of the difference between the arithmetic means (D_m) for the soil layer differentiated into genetic horizons A, B and C was demonstrated ($D_m > 3$) except for the difference between the B₁ and B₂ horizons. In studying the soil compaction, therefore, it is necessary to determine the bulk density in each genetic horizon. Lower down, in the C₁ (carbonate) and C₂ (carbonate and sulfate) horizons from 48-156 cm, D_m was less than 3; that is, the difference was not demonstrated. From this it follows that any bulk density value —

¹Values of n vary since all samples were not determined from the same depths.

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Table 4

Physical properties of solonetz: Virgin, plowed and under shrub

Solonetz	Horizon	Depth, cm	Specific gravity of soil, d_v				Specific gravity of soil particles, d				Total porosity %
			n	M $\pm$ m	P%	D_m	n	M $\pm$ m	P%	D_m	
Virgin	A	0—4	14	1,37 $\pm$ 0,019	1,4	>3	13	2,57 $\pm$ 0,015	0,6	<3	46,7
	B ₁	15—19	14	1,46 $\pm$ 0,019	1,3	<3	15	2,61 $\pm$ 0,017	0,7	<3	44,1
	B ₂	20—24	8	1,42 $\pm$ 0,023	1,6	<3	10	2,67 $\pm$ 0,023	0,9	<3	46,8
	C ₁	48—52	18	1,54 $\pm$ 0,019	1,2	>3	13	2,71 $\pm$ 0,014	0,5	<3	43,2
	C ₁	70—74	6	1,51 $\pm$ 0,027	1,7	<3	8	2,69 $\pm$ 0,028	1,0	<3	43,9
	C ₂	152—156	13	1,53 $\pm$ 0,020	1,3	<3	8	2,69 $\pm$ 0,009	1,3	<3	43,1
	C ₂	200—204	4	1,47 $\pm$ 0,044	2,9	<3	3	2,70 $\pm$ 0,033	1,2	<3	45,6
Plowed	A+B plowed	0—4	12	1,22 $\pm$ 0,030	2,5	<3	10	2,59 $\pm$ 0,019	0,7	<3	52,9
		10—14	10	1,33 $\pm$ 0,029	2,2	<3	11	2,61 $\pm$ 0,026	1,0	<3	49,0
		20—24	11	1,35 $\pm$ 0,030	2,2	<3	11	2,62 $\pm$ 0,020	0,8	<3	48,5
	B ₂	35—39	8	1,48 $\pm$ 0,018	1,2	<3	8	2,65 $\pm$ 0,026	1,0	<3	44,2
	C ₁	58—62	4	1,57 $\pm$ 0,020	1,3	<3	5	2,66 $\pm$ 0,013	0,5	<3	41,0
	C ₂	75—79	4	1,55 $\pm$ 0,043	2,7	—	—	Not det'd.			
	C ₃	125—129	2	1,49	—	—	2	2,65	Not det'd.		44,2
Under young shrubs	A+B plowed	0—4	9	1,22 $\pm$ 0,013	1,1	>3		2,56 $\pm$ 0,021	0,8	<3	52,4
		10—14	10	1,30 $\pm$ 0,009	0,7	>3	14				
		20—24	6	1,34 $\pm$ 0,008	0,6	>3	10	2,59 $\pm$ 0,021	0,8	<3	49,8
	B ₁	25—29	3	1,51 $\pm$ 0,005	0,3	>3	11	2,59 $\pm$ 0,016	0,6	<3	48,3
	B ₂	35—39	11	1,34 $\pm$ 0,024	1,7	>3	15	2,65 $\pm$ 0,016	0,6	<3	46,0
	C ₁	50—54	3	1,55 $\pm$ 0,018	1,2	>3	6	2,70 $\pm$ 0,020	0,7	<3	42,5
	C ₂	75—79	3	1,57 $\pm$ 0,010	0,6	<3	8	2,72 $\pm$ 0,021	0,8	<3	42,3
	C ₃	125—129	5	1,50 $\pm$ 0,031	2,1	<3	8	2,69 $\pm$ 0,025	0,9	<3	42,4

Note: Comma represents decimal point.

1,54, 1,51, 1,53 — can be used for the characteristic of the whole layer indicated and can be determined for any one of these horizons with any particular number of repetitions.

At a depth of 200 cm the bulk density of the soil skeleton is 1,47, the typical value for the Yergeni loess-like clay loams, which have been little affected by soil-formation processes.

The compaction of plowed solonetz was less than that of the virgin land only in the layer corresponding to the depth of plowing: at a depth of 50 cm it was roughly the same as in the virgin solonetz. The reliability of the difference M between the plowed (A + B), B₂ and C₁ horizons was shown; that between the C₁ and C₂ horizons was not.

The compaction under shrub plantings as compared with virgin land and partly plowed solonetz decreased in the 0-40 cm layer, where the main shrub root mass was situated, except in the case of the B₁ layer (25-29 cm). The roots loosen the soil even to a depth of 40 cm, but this was not reflected in the values, since the samples for determining d_v were taken from spaces between the roots rather than near the

roots, which do not form a thick network in the C₁ and C₂ horizons. A more precise method (permeability of the soil) indicated that the illuvial C₁ and C₂ horizons were also loosened by shrub roots.

The values of m and P calculated for all the horizons and soils show that the Kachinskiy instrument gives a high degree of accuracy in determining the bulk density of the soil.

The particle density of the soil was determined with a pycnometer, replicated three times. The value depends on the mineralogical and chemical composition of the soil and is little affected by its condition of cultivation. In all the soils investigated the value of d was lowest in the top layers (2.56-2.61) and highest in the lower layers (2.62-2.72). The accuracy of the determination was entirely satisfactory — % P in our investigations varied from 0.5-1.2%.

Total porosity (calculated from the figures for specific gravity of the solid phase and bulk density of the soil). The total porosity value depends on the soil compactness. The total porosity value for virgin solonetz obtained by using the appraisal scale for the physical

properties of soils suggested by Kachinskiy (10) is unsatisfactory so far as cultivated crops are concerned. The porosity increases with depth of plowing and under shrubs in the upper 40 cm layer.

Water intake into soil fairly accurately reflects the physical structure of the soil in its natural state and when modified by agricultural practices and meliorative measures. Water added to the topsoil for 1 hour, or sometimes even for 2 hours, is absorbed, but after this time the intake rate is markedly slower. During the first hour of the observations on virgin solonetz a 17 mm depth of water was absorbed; during the second and subsequent 4 hours the rate of water intake was almost constant at 5.0-2.3 mm per hour (average 3.3 mm per hour, see Table 5). This value can be provisionally taken as representing the water permeability through the top water-saturated layer, since the soil below was not water saturated.

In plowed solonetz the water intake in the first hour (28 mm) was higher than in the virgin soil but here again it dropped sharply and in the third to sixth hours varied between 11.8 and 6.8 (average 9.3) mm per hour.

The water intake into solonetz soils under young shrub plantings was roughly three times higher than in the virgin soil and twice as high as that of the plowed soil, varying between 13.4 and 16.2 mm (average 14.6 mm per hour) in the third to seventh hours of observation.

The influence of the shrubs on the soil increases with their age and depends on their biological characteristics. In solonetz under three-year-old yellow acacia a continuous application of water for 6 hours added 109.8 mm of water into the soil; under sixteen-year-old yellow acacia the corresponding value was 298 mm depth of water. It was found that the water intake of solonetz sharply increased under three-year-old Tamarix with a strongly developed root system. The root system of the box-elder, on the other hand, is poorly developed and its influence on the water intake is far less (Table 6).

Soil moisture regime. Owing to the accumulation of snow by shrubs, the greater intake of water into the soil under shrubs and the fact that summer evaporation from the soil is less, solonetz under shrubs have larger moisture contents than virgin solonetz. After thaw, the wetting depth of soils under shrubs rises to 150-200 cm and higher, against 80-100 cm in plowed and 20-30 cm in virgin solonetz. Throughout the years of observation the moisture contents in the soil to a depth of 3 m under Elaeagnus, yellow acacia and Tamarix was higher than in virgin solonetz (Table 7). The only exception was the unusually dry year 1957, when from April to July inclusive there were only 24 mm of precipitation (from 2.5-8.1 mm per month) and as a result of the strong dry winds the soil under shrubs, particularly those situated at the edge of the forest (Elaeagnus and Tamarix) dried out at a much higher rate than

Table 5

Water-intake in solonetz soils (virgin, plowed and under shrub) in mm per hour as obtained from three measurements of slightly flooded areas

Solonetz	Observation hour	Number of measurements, n	M ± m	Experimental accuracy, P%,
Virgin	First	7	17,4±0,68	3,9
	Second	6	7,1±1,14	16,0
	Third	9	5,0±0,97	19,4
	Fourth	9	3,6±1,17	32,5
	Fifth	8	3,1±0,64	20,6
	Sixth	8	2,3±0,46	20,0
Plowed	First	17	28,7±1,74	6,1
	Second	17	14,6±1,52	10,4
	Third	17	11,8±1,74	14,7
	Fourth	17	9,5±1,22	12,8
	Fifth	17	9,2±1,31	14,2
	Sixth	17	6,8±0,92	13,5
Under young shrub	First	17	53,6±3,46	6,5
	Second	17	27,3±2,37	8,6
	Third	17	13,4±2,31	17,2
	Fourth	17	16,2±2,09	12,9
	Fifth	17	15,1±1,38	9,1
	Sixth	17	13,8±1,51	10,9

Note: Comma represents decimal point.

Table 6

Water-intake of solonetz soils under various shrubs, mm depth of water

Shrub	Age	Observation hour						Total amt. of water absorbed in 6 hours of observation
		First	Second	Third	Fourth	Fifth	Sixth	
Tamarix	3 years	88,8	51,6	39,6	33,6	31,2	30,6	275,4
Box-elder	3 "	66,8	14,0	8,5	7,7	3,8	3,7	104,5
Yellow acacia	3 "	49,2	15,0	14,4	9,6	13,2	8,4	109,8
" "	16 years	140,0	50	33,0	27,0	23,0	20,0	293,0

Note: Comma represents decimal point.

Table 7

Total soil moisture contents during growing period on virgin solonetz and solonetz under various shrubs (in mm)^a

Soil layer, cm	Treat-ment ^b	1955				1956			1957				1958				
		Months															
		Apr.	June	July	Sept.	May	July	Aug.	May	June	July	Aug.	May	June	July	Aug.	
0—100	1	212	150	149	149	228	129	139	173	145	154	152	268	163	—	165	
	2	331	227	207	169	249	159	158	198	152	145	132	278	287	190	177	
	3	246	210	182	165	280	167	151	228	189	200	176	239	233	172	173	
	4	337	271	162	151	308	146	134	167	148	150	139	300	294	249	196	
100—200	1	170	143	147	156	153	182	165	159	144	144	137	165	159	—	160	
	2	282	208	223	208	201	189	214	172	192	209	189	254	232	212	236	
	3	208	209	210	195	190	203	192	188	188	159	189	191	226	173	185	
	4	194	267	214	175	195	176	184	184	190	153	171	291	270	250	186	
200—300	1	—	—	—	—	—	—	—	155	130	143	—	163	174	—	175	
	2	—	—	—	—	—	—	—	166	190	199	178	147	225	256	250	
	3	—	—	—	—	—	—	—	188	177	167	190	228	185	262	198	
	4	—	—	—	—	—	—	—	194	170	167	191	261	246	—	187	

^aMoisture content corresponding to maximum hygroscopicity for the first meter was 144 mm and for the second meter 154 mm.^b1 — virgin; 2 — Elaeagnus; 3 — yellow acacia; 4 — Tamarix.

Note: Comma represents decimal point.

that under natural herbaceous vegetation. Bearing in mind that the moisture corresponding to maximum hygroscopicity (wetting moisture content) averages 144 mm in the first and 154 mm in the second meter, we see from Table 7 that only in the dry year of 1957 were the moisture contents under Elaeagnus and Tamarix in August slightly less than the wilting moisture content limit; in all the other years the soil moisture contents to a depth of 3 m under shrubs exceeded the unavailable moisture limit.

As our investigations showed, available moisture for plants was present throughout the whole profile of the virgin soil and the soil

under perennial grasses only during the first month or month and a half of the growing period, except in wet years. In subsequent months the moisture contents in these soils were equal to or less than the wilting moisture contents. Shrubs, therefore, improve the availability of soil moisture.

Conclusions

1. It has been found from cultivating shrubs on solonetz that many shrubs are tolerant of the solonetz and solonchak properties of the

soil, develop satisfactorily on solonchets and substantially improve their properties; they can therefore be used for meliorating solonchets.

2. Owing to the secretions from living shrubs roots and the decomposition of litter with a high calcium content, the soil is desoloncheted and enriched in nutrients and the biological activity of the solonchets is increased.

3. Owing to their thick root system, shrubs have an important meliorative effect on solonchets, by loosening the soil and thereby changing its physical properties (decreasing compactness, improving porosity and sharply increasing water intake). The degree in which the shrubs affect the soil depends on their species and age.

4. Water permeability and water intake in solonchets under shrubs are two to three times greater than in virgin and plowed solonchets; this means that almost all the rain and thaw waters can be absorbed by the soil.

5. Owing to the better water-permeability of solonchets under shrub and the greater snow-retention of shrub plantings, the wetting depth in spring increases to 150-200 cm or more, against 30-40 cm in virgin solonchets, with the result that the soil moisture contents under shrubs are considerably greater.

6. The larger soil moisture contents and greater wetting depth modifies soil formation by improving leaching and promoting desalinization.

7. The changes in the physical and chemical properties and regimes of solonchets under the influence of shrubs make for improved agricultural meliorative and forest growth properties and for higher fertility.

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1. ANTIPOV-KARATAYEV, I. N., I. A. YURIN, L. A. FROLKINA, and G. M. KADER.

CHANGES IN THE PODZOLIC SOILS OF THE MURMANSK REGION UNDER CULTIVATION

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Owing to their unfavorable physical, physico-chemical and biological properties, little farming was done on the Murmansk Region soils in the past and despite the efforts of individual scientists to demonstrate the possibility of reclaiming the Kola peninsula soils, these were not used agriculturally before the Revolution.

After the October Revolution farming was started in the northern regions owing to the growth of industry and population there. In view of the arctic conditions of the region the first soils to be reclaimed for agriculture were the coarse-textured soils on southern, south-eastern and southwestern slopes, together with those in the valleys, where there is no permanent excess moisture and the permanently frozen layer is deep or does not exist at all.

Agriculture now flourishes in the Far North and is practiced in soil conditions as far as the 68th-69th north parallel in the European part and the 70th-71st north parallel in the Asiatic part of the Soviet Union. This success is due not only to the acclimatization of agricultural crops and intensive mechanization of agriculture but also to a change in the direction of the soil formation process and improvement in the agronomic properties of the soils.

As many investigators have shown, substantial changes occur in the composition and properties of podzolic soils when they are cultivated. One of the first scientists to draw attention to the cultivation of podzolic soils was A. I. Stebut. A. N. Engel'gardt also worked on aspects of this question for a long time and S. P. Kravkova, K. K. Gedroyts, P. S. Kossovicha, D. I. Mendeleyev, V. R. Vil'yams, P. F. Garbush and many other scientists devoted a number of papers to the subject.

Among published material on soil cultivation questions in the Far North we may mention the papers by Ivanova and Polyntseva (6), Zaytsev and Golubeva (5), Kononova (7), Okhotin (9), Balashov (3), Ponomareva (10, 11), Turnas (13), Chekalov (15), Tsynlenkin (14), Aderikhin (1), Aderikhin and Tikhova (2), Kosheleva and Tolstukhina (8), Shtrobinder (16), Burokova and Korsakova (4) and others.¹

It has been established in the foregoing research that Far Northern soils undergo substantial changes both in chemical composition and in their physical-chemical and biological properties when reclaimed and used agriculturally.

Our objective was to determine what changes took place in the soil in certain chemical components and physical-chemical properties of the iron-humus podzols, when reclaimed and used agriculturally, on an experimental plot in the Polar Botanical Garden of the Kola branch of the USSR Academy of Sciences and the polar state farm "Industriya." These places are in the northern part of the European taiga, where natural conditions are severe and unfavorable for agriculture. Since they have been described in detail in a recent paper by Polyntseva (12) we shall not dwell on their characteristics here, nor need we describe the soil of the Industriya state farm and the experimental part of the Botanical Gardens, which were also described in detail in that paper. Our observations and investigations were made in forests and fields occupied by iron-humus podzols. The genetic and morphological characteristics are shown below.

Profile 2. Iron-humus podzols. Experimental plot of the Botanical Garden. Pine forest around corn field.

A₀ 0-2 cm. Forest litter.

A₂ 2-6 cm. Podzolic horizon, white in color, slightly moist, penetrated by roots, sandy loam.

B₁ 6-13 cm. Illuvial horizon, ocher colored, moderately moist, penetrated by roots.

B₂ 13-32 cm. Muddy yellow with greenish tints, moist.

C Below 32 cm. Moraine, muddy red brick color, clay loam, with boulders.

of the USSR Academy of Sciences, where research on questions of soil cultivation has been going on for many years, has manuscript material by N. P. Belov, A. I. Lyakhova and O. A. Polyntseva.

² The influence of phosphoric acid intake on soil structure. Pochvovedeniye, 1951, No. 4.

¹ In addition to published papers, the polar branch

Table 1

Particle size analysis of iron-humus podzols (in % absolutely dry soil)

Profile No.	Horizon	Depth, cm	Separates, mm							Texture
			1-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	< 0,001	< 0,01	
2	A ₂ C	2-6	24,96	53,13	13,73	2,15	2,48	3,55	8,15	Cohesive sand
		32 and below	24,8	23,46	27,23	5,52	11,12	7,87	24,51	Coarse clay loam
1	A _{plow} C	0-19	26,5	53,42	13,56	1,66	0,66	4,26	6,52	Cohesive sand
		38 and below	6,25	34,38	51,93	2,99	0,61	3,81	7,41	Cohesive sand
9	A ₂ C	2-6	39,24	38,04	12,76	4,07	1,45	4,39	9,91	Cohesive sand
		46-70	22,96	55,17	16,84	1,12	2,16	1,75	5,03	Cohesive sand
5	A _{plow} C	0-20	55,26	29,00	4,73	4,49	1,62	4,91	11,02	Sandy loam
		39-60	86,66	9,31	1,02	1,18	1,12	0,71	3,01	Cohesive sand

Note: Comma represents decimal point.

Profile 1. Iron-humus podzols (cultivated variety). Experimental plot of the Botanical Garden; plowland - corn field.

moist, with ocher spots, sandy loam.

A_{plow} 0-19 cm. Muddy yellow, slightly

B₂ 19-33 cm. Ocher colored, penetrated by grass roots, moist, compacted.

Table 2

Humus and exchangeable cation content in iron-humus podzols

Profile No. and land use	Horizon	Depth, cm	Hygroscopic moisture, %	Humus, % (according to Tyurin)	Total exchangeable cations	Exchangeable acidity	Active Al content
					meq/100 g of soil		
2. Botanical Garden forest	A ₂	2-6	0,46	0,46	0,23	0,91	0,84
	B ₁	6-13	2,01	1,63	2,01	0,42	0,33
	B ₂	13-32	2,05	0,32	—	0,09	0,01
	C	32 and below	0,94	0,12	1,68	0,26	0,15
1. Botanical Garden plowland	A	0-19	2,52	3,30	2,96	0,32	0,23
	B ₂	19-29	3,18	0,71	0,78	0,12	0,04
	B ₃	29-38	2,51	0,52	2,08	0,10	0,02
	C	38 and below	1,56	—	1,00	0,13	0,06
6. Industriya state farm forest	A ₂	2-6	0,24	0,74	0,14	0,95	0,71
	B ₁	6-26	3,52	2,4	0,79	0,50	0,41
	B ₂	26-40	3,74	0,97	—	0,09	0,01
	C	40-70	0,39	—	0,96	0,49	0,40
5. Industriya state farm plowland	A	0-20	4,29	4,33	5,58	0,24	0,14
	B ₂	20-39	2,8	2,102	4,44	0,14	0,04
	C	39-60	1,34	0,35	0,910	0,08	0,01

Note: Comma represents decimal point.

C below 33 cm. Coarse greenish sand.

Profile 6. Iron-humus podzol. Pine forest. Industriya state farm near potato field.

A₀ 0-2 cm. Cinnamon-brown litter.

A₂ 2-6 cm. Podzolic horizon, white color.

B₁ 6-29 cm. Light ocher, slightly compacted.

B₂ 29-46 cm. Muddy ocher color, some pebbles.

C 46-70 cm. Coarse sand with greenish tint.

Profile 5. Iron-humus podzol (cultivated variety). Plowland. Potato field of Industriya state farm.

A_{plow} 0-20 cm. Grey, slightly moist, skeletal, penetrated by roots.

B₁ 19-28 cm. Light ocher colored.

B₂ 28-47 cm. Greyish ocher color, occasional pebbles, passing to cemented C horizon.

C 47-69 cm. Coarse sand, greyish muddy green color, with orange sandstone, slightly cemented.

The morphological characteristics of these

soils indicate that radical changes have taken place in the profile in the course of cultivation. The iron-humus podzols have lost their typical natural characteristics and the A₂ horizon has completely disappeared.

The Kachinskiy pipette method was used for the particle-size analysis, the results of which are shown in Table 1. Texturally these soils are mainly cohesive sands. In the experimental plot of the Botanical Garden the texture starts to become finer with depth, whereas in the plowland of the Industriya state farm the opposite occurs. It did not prove possible to find how the texture changes under the influence of cultivation.

The forest and plowed soils were found to differ substantially in chemical composition and physical-chemical properties (Table 2). The humus content in the top A₂ horizon of the non-cultivated forest soils is only a few tenths of 1 percent (the A₀ litter horizon was not analysed) whereas in the B horizon it increases owing to migration from the upper horizon, where a process of podzol formation takes place under the forest cover. The plow horizon in the experimental plot contains 3.5 times more humus, and the plowland in the Industriya state farm 5 times more than the A₂ horizon under forest. The higher humus content has been produced as a result of man's agricultural activity. The humus amount in the B₂ horizon of the plowland falls sharply, probably because the root systems of the plants are mainly concentrated in the top plowed layers. In the C horizon there is

Table 3

Phosphate groups according to F. V. Chirikov in iron-humus podzols and their P₂O₅ adsorption (in mg per 100 g of soil)

Profile No. and land use	Horizon	Depth, cm	Phosphate groups, soluble in:			P ₂ O ₅ adsorption
			H ₂ O+CO ₂ I	0.5 n CH ₃ COOH II	0.5 n HCl III	
3. Forest, experimental plot of Botanical Garden	A ₂	2-6	0,95	2,07	10,31	None
	B ₁	6-13	1,96	2,06	27,6	439,19
	B ₂	13-32	—	1,99	93,8	282,8
1. Plowland, experimental plot of Botanical Garden	A	0-19	0,498	4,03	95,3	125,1
	B ₂	19-29		Not det'd.		505,8
	B ₃	29-38	0,9	1,95	70,5	315,4
	C	38 and below	0,483	4,34	67,6	None
6. Industriya state farm forest	A ₂	2-6	—	2,01	9,05	None
	B ₁	6-26	1,03	4,09	71,08	362,4
	B ₂	26-40	4,88	7,99	92,72	287,2
	C	40-70	1,02	16,5	91,96	None
5. Industriya state farm plowland	A	0-20	—	8,00	96,9	297,8
	B ₂	20-39	—	—	64,7	431,8
	C	39-60	—	3,85	43,5	None

Note: Comma represents decimal point.

hardly any humus at all.

As can be seen from Table 2, according to the findings of G. Kappen-Gil'kovits, the total quantity of exchangeable cations in the soils studied is negligible. Comparison between the forest and the field soils shows a marked difference in the exchangeable cation content in the topmost horizon. In the forest of the Botanical Garden experimental plot, for example, this total is 0.23 meq whereas in the plowland it is 2.96 meq; in the Industriya forest it is 0.14 meq against 5.58 meq in the plowland. This pronounced increase in the amount of exchangeable cations in the plowland is due to the higher humus content in that horizon and the more intensive weathering of the mineral part of the soil under the influence of man's agricultural activity. Conversely, exchangeable acidity in the plowed soil has fallen to one-third of that in the forest soil. The same pattern was found in both the observation areas. Exchangeable acidity decreases with depth. This is due to the weakening of the soil formation process. A. V. Sokolov's determination of active aluminum has made it possible to find which of the ions causing an acid reaction predominates in the given soils. As Table 2 shows, the active aluminum content in the top horizons is several times higher than the hydrogen ion content. In the field soils the amount of active aluminum has in all cases decreased sharply as compared with the forest soils. This is useful, since it improves the medium for the development of microorganisms, reducing its toxicity, and consequently creates more favorable conditions for the development and growth of crops.

In order to examine how the soil phosphates have changed as the result of cultivation we separated phosphate groups by a simplified version of the Chirikov method both in the cultivated and in the noncultivated soils. Table 3 shows that the amount of group I phosphates in the top horizon was small. The forest soil was noticeably richer in this form of phosphate than the plowed soil, probably because of the higher acidity of the forest soils. The amount of group I phosphates increases in the illuvial horizon but decreases in the C horizon. The top horizon contains more group II than group I phosphates, but in comparison with other soils, for example, chernozems, the content is not great and is too small to meet the phosphorous needs of the plants. As a result of several years cultivation it has been found that the group II phosphate amount has sharply increased—a positive finding, indicating that the cultivation of the soils has reached a certain level. These phosphates are distributed unevenly along the profile, owing to the peculiarities of the soils concerned. As a rule, the C horizon contains more group II phosphates than the B horizon; this indicates that the local parent materials are rich in phosphorus.

The amount of group III phosphates in the top horizons is very much greater than the amount of group I and II phosphates, particularly in the cultivated soils. In the natural iron-humus podzols the group III phosphate content is 5 times higher than the group II phosphate content, whereas in the cultivated soils it is 12-24 times higher. Comparison of the group III phosphate content in the top horizon of the natural and the

cultivated soils shows that there is a sharp improvement (9-10 times more) when the soils are correctly used for agricultural purposes. The higher amount of phosphates in the top plowed layer is due to the application of organic and mineral (phosphoric) fertilizers and the biological accumulation of phosphorus through the direct participation of crops. Consequently, proper use of the soils under the conditions we are dealing with enriches them in phosphorus and creates a phosphorous reserve.

The distribution of group III phosphates in the soil profile is interesting. In the noncultivated soils the quantity steadily increases with depth, whereas in the cultivated soils the opposite is true. The maximum group III phosphate amount in the plowed soils is found in the A horizon; in the forest soils it is in the C horizon. This distribution indicates that in the conditions of the forest area, where there is intensive podzol formation, phosphorous accumulation in the top horizon does not occur, because the readily soluble phosphates are transferred from the upper to the lower horizons in the course of the soil-forming, weathering and leaching process. In the fields, on the other hand, where the soils are being properly used and sown to crops, there is intensive biological accumulation of phosphorus in the top horizon where plant roots and microorganisms play a direct part. The fact that the quantity of group III phosphates in the cultivated soils decreases down the profile indicates that there is no transfer of readily soluble phosphates from the upper into the lower horizons of these soils and that the podzol forming process has ceased here.

Proper use of the iron-humus podzols for agricultural purposes consequently changes the conditions and trend of soil formation and makes for the suppression of the podzol forming process and the development of the sod process.

At the same time as studying the changes in forms of phosphorus in these soils we were also interested in comparing the phosphate ion adsorption by the noncultivated and the cultivated iron-humus podzols. For this purpose we tested the PO_4^{3-} by a method described by Aderikhin.² As Table 3 shows, the adsorption capacity of the top horizons in regard to phosphate ions differs according to whether the soil is cultivated or not: in the latter case there is no PO_4^{3-} adsorption in the upper podzolic horizons, whereas in the upper horizons of the cultivated soils large quantities of PO_4^{3-} are adsorbed. A similar difference between the field and forest soils is found in regard to the PO_4^{3-} adsorption capacity in the lower horizons. This is much higher in the cultivated than in the noncultivated soils. In both, however, the peak value for phosphate ion adsorption is found in the illuvial horizons which are rich in sesquioxides.

The high phosphate adsorption capacity of the cultivated soils and the illuvial horizons of the noncultivated iron-humus podzols obliges us to take steps to reduce the phosphate adsorption when applying phosphorous fertilizers into these soils, in order to increase the effectiveness of these fertilizers. Such measures include, in particular, modifying the acid reaction of the soil in the direction of neutralization by liming and applying organic fertilizers in the form of

pulverized peat or compost; water-soluble phosphorous fertilizers, on the other hand, should be applied in granulated form.

Conclusions

1. As a result of prolonged agricultural practices the genetic and morphological profile of the soils studied has radically changed and the A₂ horizon has disappeared.
2. As a result of many years of cultivation, the top layers of the soils have been notably enriched in humus.
3. As a result of many years of crop-growing the quantitative content and ratio of adsorbed cations has altered: the total amount of exchangeable Ca and Mg in the top horizons of the cultivated soils has increased and the H and active Al content has decreased in comparison with the non-cultivated soils; the soil acidity has been correspondingly reduced.
4. The cultivated soils contain more available phosphates (groups I and II) in the top horizon than the non-cultivated ones. There is also a considerably greater amount of group III phosphates in the cultivated soils, the peak quantity being found in the A horizon whereas in the noncultivated soils it is in the C horizon.
5. Cultivation of the soils increases their adsorption capacity for P₂O₅ in the top horizon, with the result that phosphorus accumulates there.
6. When the soils under consideration are correctly used for agricultural purposes the trend of the soil-formation process alters and the soils become similar to southern latitude soils; this is accompanied by an improvement in all their physical-chemical and agronomical properties.

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THE TRANSBAYKAL MOUNTAIN-TUNDRA LANDSCAPES

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Our use of the term geographical landscape is based on Polynov's definition (11): "Landscape is any part of the Earth's surface where climate, geological structure, relief, basins, vegetation, soil and animals consistently retain a specific composition and specific characteristics to such an extent as to result in uniformity of the processes by which they interact one upon another... The connection between these elements should not be regarded as a state of equilibrium... This connection is loose... and represents the development of landscape... Climate and geological structure are the primary factors which largely determine the general shape of the landscape and modifications in them are reflected in the landscapes in the most basic way."

The existence of a landscape peculiar to the mountain-tundra has been established by Tyulina (20), Gorodkov (3), Sochava (14, 15), Bogatyrev (1), Petrov (10), Liverovskiy (6) and Mikhaylovskaya (8). Little study, however, has been made of the landscape and soil of the Eastern Siberian and Transbaykal mountain-tundra, although this is the region in which the mountain-tundra landscapes primarily occur (15).

We have distinguished two types of mountain-tundra landscape in the Transbaykal Region: 1) the mountain-tundra or gol'ts landscapes proper and 2) the mountain-lowland tundra landscapes.

Gol'ts Landscapes

By mountain-tundra or gol'ts landscapes proper we understand them to be a combination pattern of gol'ts relief, mountain-tundra vegetation and mountain-tundra soils, where the climate is of the severe temperate-continental type similar to that of the lowland tundra.

¹The material on which this paper was based was collected by the authors in the course of travelling research expeditions in 1953 and 1955 made as part of the Buryat-Mongol joint expedition of the SOPS (Council for the Study of Productive Resources) of the Academy of Sciences, USSR, in 1956 as part of the joint SOPS expedition and in 1957-1958 as part of the Transbaykal soil expedition of the Dokuchayev Soil Institute, Academy of Sciences, USSR.

The gol'ts landscapes of which descriptions already exist are in Transbaykal, the northern part of the Cis-Amur region, Sikhote-Alin, the Verkhoyansk range, the Alyaska, Anadyr and Chukotka, the Chekanovskogo range, the Urals, the Sayany, the Altay and Tuva. Gol'ts landscapes are characteristic of the subnival zone of high continental mountains in the temperate belt (19). In the subnival zone of the cold belt they are replaced by highland arctic desert landscapes and in the subtropical belt by cold high-mountain desert landscapes. In high-mountain areas with an oceanic climate they are replaced by alpine landscapes.

The Transbaykal gol'ts landscapes associate mainly with the summit belt of inland mountains and are found at an altitude of the order of 1600-2000 m above sea-level. In the high mountain ranges of the Cis-Baykal and northern Transbaykal regions, which have a winter climate, the predominant landscapes are alpine and sub-alpine (12a).

The climatic conditions of the Transbaykal gol'ts belt are very peculiar and cannot be defined on the basis of data from meteorological stations situated in the hollows between the mountains. Since hardly any systematic meteorological observations have been made in the Transbaykal gol'ts we have used the results obtained from short-term observations by various investigators and data provided by the gol'ts meteorological stations in neighboring territories. The gol'ts climate is characterized by a mean annual temperature of about -6°C and a mean annual precipitation of the order of 400-500 mm. The summer is brief, cold and rainy. The mean July temperature is about 12°C . The sum of temperatures above 10°C is about 300°C . The frost-free period lasts less than two months; there is no guarantee that a single summer month will be free from frosts. Most of the precipitation falls in the summer months. The winter is cold, but owing to temperature inversions the mean temperature in January does not fall below -25.0°C or the average absolute minimum below -40°C . The snow cover is established at the end of August and disappears at the beginning of June. The distribution of snow is very irregular. The snow is blown down from the flat summits of the gol'ts and the gol'ts terraces and accumulates under the latter in the form of thick snow drifts. In spring and autumn the temperature repeatedly falls below 0°C . As

a result of the severe winters, in which there is little snow, permafrost is general throughout the gol'ts zone.

In so severe a climate, with its cold winters without much snow and numerous variations of temperature through 0°C , the principal relief-forming factors are the processes of frozen ground and frost weathering and solifluction, which form the peculiar "gol'ts" relief. The characteristic feature of this relief is huge dome-shaped configurations. The gol'ts summits are flat and may extend over several km^2 . Sometimes a cone of rock, called a *tump*, made up of weathering waste from the surface, rises to a height of several tens of meters on this flat surface. In profile, the gol'ts slopes give the appearance of a broken line. Steep scarps (gradient of 15° - 30°), several tens of meters high and covered with scattered rocks, alternate with the flat, so-called highland or gol'ts terraces. These are several tens to several hundreds of meters wide, with a gradient not exceeding 1° - 3° , and are cut into the parent rock. Their surface is overlaid with a waste mantle, 2-4 m thick. Various types of tundra micro-relief have developed on the flat summits of the gol'ts and on the gol'ts terraces, from rock seas with fine earths areas to patchy tundry with hillocks. Dozens of different hypotheses have been put forward to explain the gol'ts relief. The best founded is that of Boch and Krasnov (2) which is now generally accepted. Without going into details, we may mention that according to this hypothesis the gol'ts relief is a regional peculiarity of mountain ranges with a severe temperate-continental climate.

Two gol'ts belts can be distinguished: 1) the mountain-tundra, or gol'ts proper and 2) the forest-tundra, or sub-gol'ts. The former occupies the gol'ts summits and upper terraces. The vegetation has the characteristic features of tundra vegetation: predominance of arctic and alpine perennial and evergreen flowering plants, mosses and lichens; micro-story, mixed, mosaic type of distribution of vegetation; adaptations in the plants to conditions of excess illumination accompanied by insufficient available water, such as a waxy bloom, leatheriness, pubescence, bright leaf color and so forth. The distribution of the mountain-tundra associations depends on the moisture regime. Poorly drained habitats, where the moisture is stagnant, are occupied by various tundra moss associations. Tundra lichens and shrub lichens grow in areas where the drainage is good. A narrow belt of forest-tundra (sub-gol'ts belt) is formed by thickets of spreading cedar and alder, with areas of mountain-tundra vegetation. The gol'ts and sub-gol'ts vegetational belts differ from each other in regard to soil, since the soil distribution here depends primarily on the relief and the draining of the sub-stratum, which masks the vertical zonality. It may be that as a result of more detailed research the soils of the gol'ts and sub-gol'ts vegetational belts will be differentiated. The material at our disposal is insufficient for this. The capacity of the sub-stratum to drain depends on the thickness of the fine earth deposits, their particle-size distribution and the shape of the tundra microrelief.

Where drainage is poorest mountain tundra peaty-gley soils develop under the mossy tun-

dras. Here the microrelief becomes patchy, with small hillocks. Three horizons can be distinguished in the profile of the mountain-tundra peaty-gley soils. The peaty, black A_0 horizon, about 10 cm thick, passes into a gleyed horizon 20-30 cm thick, which is moist, thixotropic and structureless. Dark blue tones predominate in its coloring. The gleyed horizon gradually gives way to a C horizon, usually of brownish tones. This C horizon is also water saturated, since the permafrost horizon is situated at a depth of 50-70 cm. The weakening of the gley process in the C horizon is due to the low temperatures of the horizons above the permafrost, which slows the activity of micro-organisms.

Where drainage is better, mountain-tundra humic surface-gley soils form. The detailed characteristics of these will be given when we describe the lowland-tundra.

Where the sub-stratum is well drained the soils which have developed show no signs of excess wetting in their profile. Such soils predominate in the Transbaykal gol'ts zone and we shall go into their characteristics in more detail. A variety of names has been used by various authors in describing these soils in Eastern Siberia: Prasolov (12) called them "mountain-tundra," Petrov (10) "humic mountain-tundra," Nosin (9) "sod-humic mountain tundra" and Karavayeva (5) "sod gol'ts." In our view the most appropriate name is "sod mountain-tundra," the term "sod" referring to the accumulation of organic matter, in the pre-humus stage of decomposition, as distinct from humus and peat. We shall therefore reserve the term "sod mountain-tundra" for these soils throughout this paper.

The sod mountain-tundra soils develop on thin (30-50 cm) rubble deposits of varying texture on top of coarse detritus and rock fragments. A microrelief formed by polygonal stones develops on the surface, forming an excellent natural drainage system. The vegetation is lichen and grass-lichen tundra. The commonest lichens are *Cladonia rangiferina*, *C. alpestris*, various species of *Cetraria* and others. Small shrubs are fairly numerous: *Arctous alpina*, *Empetrum nigrum*, *Cassiope ericoides*, *Drias punctata*, *Vasinium vitis idaea* and others. The grass cover includes *Calamagrostis japonica*, *Poa smirnovii*, *Viola biflora*, *Bupleurum trizadiatum*, *Carex alticola*, *C. encipolia*, *Anemone sibirica* and others. The shrubs *Betula ermanii*, *B. middendorffii*, and the *Pinus pumila*, which penetrates to this region from the sub-gol'ts region, are rarely found and then only in areas protected from the wind.

The Profile of the sod mountain-tundra soils shows two distinct horizons, a grey cinnamon-brown humus horizon (A_1), 5-10 cm thick, and a brown 20 cm thick horizon underneath it, which gradually passes into the rock material. The morphology of these soils can be seen from the following description of one profile.

Profile 120. On summit of Kontalakskiy gol'ts, Yablonovyy range. Height 1640 m. Predominant vegetation: reindeer lichen, crowberry, ptarmiganberry.

Table 1
Physical and chemical properties of mountain-tundra sod soils

Profile and location	Depth, cm	Hygroscopic moisture, %	pH		Humus %	Cation adsorption, meq/100 g of soil				Unsaturation, %	Exchang. H and Al (Sokolov method)		Hydrolytic acidity	Fe ₂ O ₃ , mg/100 g of soil (Tamm method)	Clay content, %
			Water	Salt		Ca	Mg	H	Total		H	Al			
15 Mount Kropotkina	0-7	1,60	4,37	3,68	9,15	4,2	1,3	2,9	8,4	35	0,2	0,6	5,5	785	21,8
	10-20	1,00	4,54	3,66	1,69	4,6	0,5	1,1	3,2	35	0,1	1,2	2,8	1040	16,4
	20-30	0,93	4,54	3,64	1,43	1,6	0,2	1,4	3,2	44	0,1	1,2	2,8	725	18,1
	40-50	0,89	4,54	3,77	0,12	1,6	1,3	0,8	3,7	21	0,1	0,6	2,1	588	15,9
	80-90	0,47	4,79	3,85	0,10	2,7	2,0	0,6	5,3	11	0,1	0,4	2,0	743	17,2
42 Bald mountain Yablonovyy range	0-7	3,68	4,54	3,68	2,12	7,7	1,5	6,7	15,9	42	Not det'd.		2,8	318	23,3
	10-20	3,42	4,05	3,85	0,41	1,1	0,4	1,6	3,1	52	"		1,7	409	18,1
	30-40	1,13	3,83	3,77	0,08	0,7	Her	1,1	1,8	61	"		0,9	231	14,6
	0-9	2,88	4,62	3,79	9,85	3,4	1,0	3,5	7,9	44	0,2	1,3	5,5	440	21,6
	9-18	1,78	4,62	4,20	1,96	None		0,2	0,2	100	0,1	0,2	2,1	249	16,2
107 Bald mountain Kontalakiy	18-28	1,00	4,57	4,20	1,33	0,6	0,6	0,2	1,4	14	0,1	0,1	1,4	228	14,7
	3-9	2,85	4,54	3,50	5,55	0,9	0,9	3,0	4,8	63	0,2	2,2	5,0	266	25,2
	9-20	3,10	4,50	3,68	2,89	0,4	0,4	1,3	2,1	62	0,1	1,6	4,8	278	25,2
	30-40	2,87	4,50	3,68	0,89	0,4	0,1	3,1	3,6	84	0,2	3,6	4,9	200	25,2
	10-10	2,30	4,37	3,50	8,87	1,6	0,5	4,3	6,4	67	0,2	2,2			
10 Altitude 1600 m, near Mt. Kropotkina	10-20	2,31	4,62	4,02	2,13	1,1	0,2	0,2	1,5	13	0,1	0,1	6,9	371	Not det'd.
	0-3	2,85	4,54	3,68	9,05	5,4	1,3	2,5	9,2	27	Not det'd.		5,4	288	"
	3-10	2,10	4,57	3,85	4,23	1,6	0,2	1,2	3,0	40	"		6,1	316	"
	40-70	1,08	4,79	4,02	0,83	0,8	0,5	0,3	1,6	19	"		3,2	410	"
													2,8	C.n.	

Note: Comma represents decimal point.

A 0-9 cm. Greyish cinnamon-brown, moist, gravelly, rubbly, coarse clay loam, slightly blocky, penetrated by roots. Marked transition.

B 9-18 cm. Grey-brown with ochertint, gravelly, rubbly, moist, somewhat sandy, coarse clay loam. Marked transition.

BC 18-28 cm. Grey-brown, moist, coarse clay loam, a great deal of rubble with iron film on its lower surface.

C 28-32 cm. Continuous rock detritus.

The sod mountain-tundra soils possess an acid reaction throughout the profile; slightly higher acidity is characteristic of the top horizons, but this increase is negligible. The water pH varies between 4 and 5, the salt pH between 3 and 4. The acidity is due to adsorbed aluminum. Hydrogen adsorption is found only in the humus horizon, in negligible amounts (Table 1).

The organic matter content in the humus horizon of the sod mountain-tundra soils is usually 3%-10%. In the B horizon it decreases to 2%-3%; still lower, it is less than 1%. As Petrov's investigations (10) have shown, fulvic acids predominate in the group composition of the humus and mobile fractions in the composition of the humic and fulvic acids.

The adsorption complex of the sod mountain-tundra soils is usually 20%-60% unsaturated. The remaining 80%-40% of the capacity is made up of Ca and Mg. In all the profiles examined, particularly the B horizon, the very low adsorption capacity is striking. Where there is a clay fraction (profile 120, depth 9-18), 0.2 meq/100 g of soil, or 1.2 meq/per 100 g of clay fraction, accounts for 16% of the adsorption capacity. We regard these low adsorption capacity values as connected with the high mobile iron hydroxide content in the top horizons of the sod mountain-tundra soils. The maximum amount of iron ex-

tracted with Tamm's extract is usually found in the B horizon, which contains 300-1000 mg per 100 g of soil, apparently owing to the nature of the weathering and organic residue breakdown processes. In two profiles (Nos. 120 and 10) the maximum amount of mobile iron is found in the A horizons. This phenomenon usually occurs in the first stages of soil formation in tundra soils developed on igneous rocks (18). As a result of the severe winter freezing in the top horizons dehydration takes place, accompanied by irreversible coagulation of the colloidal iron compounds. The iron loses mobility and forms films on the surfaces of the soil particles, reducing the soil's adsorption capacity. In order to check this hypothesis, the adsorption capacity before and after Tamm's extract was determined in profiles 107 and 120. As Table 2 shows, the removal of iron from the B horizon of the sod mountain-tundra soils with Tamm's reagent increased the adsorption capacity.

For purposes of comparison similar determinations were made in the humus-gley mountain-tundra soil. Here, the results obtained were the opposite: the adsorption capacity decreased after treatment with Tamm's reagent. Irreversible fixation of the iron in this soil is obviously impossible, owing to perpetual excessive wetting; moreover, it may be assumed that in the humus-gley soils the winter temperatures never reach such low values as in the sod mountain-tundra soils, because of the peaty or humus layer, which is an excellent heat insulator. The decreased adsorption capacity in the humus gley soil after extraction with Tamm's reagent is due to the partial destruction and transfer of organic and mineral compounds by the reagent. In all probability, the iron in the sod mountain-tundra soils is also a structure-forming factor.

As regards the position of these soils in the modern soil classification, we are in agreement with the point of view expressed by Petrov (10). We believe that the sod mountain-tundra soils are an independent group formed on a well-drained

Table 2

Change in adsorption capacity of mountain-tundra soils after treatment with Tamm's reagent

Profile No. and soil	Depth, cm	Adsorption capacity, meq/100 g	
		Bef. treat. w/Tamm's extract	Aft. treat. w/Tamm's extract
120 Mountain-tundra sod	0-9	8,3	6,7
	9-18	0,8	2,8
	18-28	2,3	3,0
107 Mountain-tundra sod	3-9	5,3	10,3
	9-20	2,8	5,1
	30-40	8,4	9,3
37 Mountain-tundra humic surface-gley	0-10	78-0	44,0
	10-20	37,0	26,5
	25-35	11,5	8,7
	50-60	11,6	8,7

Note: Comma represents decimal point.

sub-stratum in the mountain-tundra landscape. On slightly or poorly drained sub-strata, other conditions being similar, mountain-tundra gley soils develop. The picture is similar in the case of the lowland tundra, the only difference being that it is very difficult to find well-drained areas in these lands because of the flatness of the contour and the thick mantle of fine earth deposits. In these rare areas sod tundra soils develop without any signs of excessive wetting. Such soils have been described by Targulyan (17) (lower reaches of the Lena River), Tedrow (21) (Alyaska), Sochava (16) (Anabary basin), and Makarov (7) (Anadyr basin), and others.

Mountain-Valley Tundra Landscapes

Mountain tundra landscapes penetrate to the upper and middle part of the mountain taiga belt (up to an altitude of the order 1000 m) in the depressions between the ranges. A similar phenomenon, where the natural zones are reversed, has been described more than once in connection with the Chibiny, the Urals and the Altay-Sayany region and in the Far East. Usol'tsev (1857, quoted by Kryukov [5a]) was the first to report on the extensive peaty waterlogged areas, known as mari, occupied by dwarf arctic birch in the Transbaykal region. Even the earliest investigators of the Transbaykal soils classed these lands as tundras (13). The appearance of mountain lowland-tundra in the mountain-taiga belt is due primarily to temperature inversions, which play a particularly important part in the Transbaykal region owing to the sharply continental character of the climate. Another reason is the edaphic conditions. In the best drained and warmest places individual larch trees can often be found.

On the whole, the climate of the lowland-tundra is similar to that of the gol'tses, except that it is more continental and there is less precipitation. Diurnal and annual temperature fluctuations are much greater. The mean monthly temperature in July is +15°C and in January -30°C. The mean absolute minimum is -50°C. Frosts are very frequent throughout the growing period. Minimum annual precipitation is 300-400 mm, with a peak in July and August. The snow cover is less than 20 cm thick. Permafrost is universal.

The distribution of vegetation in the mountain lowland-tundra depends on the absolute altitude, the width of the depression and the drainage of the sub-stratum. Corrie-like depressions in the upper reaches of the mountain rivers are occupied by mossy and grass-mossy tundra and tundra-bog plant associations. Lower down, in the wide (1-2 km) depressions and flat low watersheds, shrubby birch tundra develops on clay loam deposits, with areas of lichen tundra on well-drained hillocks. Still lower down, the mountain lowland tundra gives place to meadows at heights of 800-1000 m.

The soil distribution depends on the same factors as the vegetation distribution. Peaty surface-gley mountain-tundra and mountain-tundra-bog soils develop under the mossy and grass-mossy associations. The morphology of these soils is on the whole similar to that of the

mountain-tundra gley soils on the gol'tses described previously, except that there is less rubble. These soils are not widespread and are not used for farming.

The mountain-tundra humic surface-gley soils described in detail previously are the predominant group in the mountain lowland tundra. These soils form under the shrubby birch tundra. The shrub canopy consists of *Betula middendorfil*, *B. ermanii*, *B. exilis*, *Ledum palustre*, *Potentilla fruticosa* and a few species of *Salix* and *Rhododendron*.

The shrubs include *Vaccinium vitis idaea* and *Vaccinium uliginosum*. In the foregoing soils various mosses and lichen predominate over grasses. The soil surface has a very pronounced microrelief of patchy tundra with small hillocks. Most investigators of the Transbaykal Region attribute the formation of this type of microrelief to the tension between the perpetually and the seasonally frozen horizons.

The soil-forming rocks here are rubbly, medium and fine clay loams of deluvial-piedmont and piedmont-solifluction origin, several meters thick.

The humic surface-gley mountain-tundra soils have a black A_0A_1 humic horizon 10-20 cm thick, which changes abruptly into a gleyed horizon. Between the humic and the gleyed horizons there is often a layer of coarse rubble, 8-10 cm thick, as a result of freezing processes. The color of the gleyed horizon varies: dark bluish grey humic streaks alternate with dark blue spots of gleyization with rust-colored concretions and other separates. This horizon often possesses thixotropic properties. The gleyed horizon gradually changes into a brownish clay loam without clear signs of gleyization. The absence of gleyization is due to the low temperatures. Permafrost is found at a depth of 60-80 cm. The whole profile is wet and a water horizon lies above the frozen horizon. There are sometimes traces of frozen mixture in the profile. Profile 125 is described below to give the morphological picture.

Profile 125. Situated 4 km north of the hamlet of Tungokochen. Very gentle, sweeping slope. Overgrowth of Altay birch, willow and ledum. Blueberry, mountain cranberry, burnet, mosses, lichens, grasses, sedges, small surface hillocks.

0-15 (6) cm. Black, moist, coarse clay loam, thickly penetrated by roots, marked transition, undulating boundary.

15 (6) -25 cm. Variable color, ocher-brown and dark bluish grey separates and patches, gravelly medium clay loam, wet, oozing water.

25-70 cm. Brown, with dark bluish grey and rust colored spots, medium loam, damp, oozes water.

The humic surface-gley mountain-tundra soils are characterized by an acid reaction throughout the profile (Table 3). The water pH varies from 4.5-5.0, the salt pH around 4.0. The surface horizons have an acid reaction, as a result of biological accumulation of cations.

Table 3
Physical and chemical properties of mountain-tundra humic surface grey soils

Profile and location	Depth, cm	Hygroscopic moisture, %		pH		Humus %	Cation adsorption, meq/100 g of soil				Unsaturation, %	Exchange of H and Al (Sokolov method)		Hydrolytic acidity	Fe ₂ O ₃ , mg/100 g of soil (Tamm method)	Clay content, %
		Water	Salt	Water	Salt		Ca	Mg	H	Total		H	Al			
28 Karenga River valley	0-10	4,38	5,18	4,62	4,62	22,97	48,6	11,6	0,6	60,8	1,0	0,1	None	1,5	294	40,5
	20-30	3,18	4,54	4,37	4,37	1,04	13,7	4,5	0,1	18,3	0,6	0,1	"	11,8	396	29,8
	40-50	4,14	4,92	4,37	4,37	1,06	14,6	5,4	0,1	20,1	0,5	0,1	"	3,7	259	29,2
	60-70	2,82	4,66	4,37	4,37	1,08	12,8	3,8	0,1	16,7	0,6	0,1	"	2,9	311	26,6
37 Yablonovyy Range	0-10	8,90	5,83	4,62	4,62	35,00	51,5	17,2	1,3	70,0	2	Not det'd.		6,4	4029	Not det'd.
	10-20	6,58	5,40	4,37	4,37	16,74	25,7	6,7	1,1	33,5	3	"	"	5,5	4930	"
	25-35	2,08	5,32	4,01	4,01	2,61	6,7	3,4	0,7	10,8	6	"	"	2,3	2031	"
	50-60	1,67	5,23	4,02	4,02	1,95	7,5	2,2	0,5	10,2	5	"	"	1,9	262	"
125 Karenga River valley	0-10	8,42	4,79	4,02	4,02	22,25	41,7	11,9	1,3	54,9	2	0,2	None	10,8	2292	50,7
	10-20	1,60	4,91	3,99	3,99	1,07	10,1	4,6	0,2	14,9	1	0,1	0,1	1,3	877	28,1
	30-40	2,32	4,91	3,94	3,94	0,70	8,5	4,8	0,3	13,6	2	0,2	0,1	1,6	4124	29,3
	60-70	3,32	4,91	3,99	3,99	0,88	11,4	5,5	0,1	17,0	1	0,1	0,2	1,6	1418	30,0

Note: Comma represents decimal point.

The humic surface-gleyed soils retain 20%-30% of the organic matter in the top horizon. This accumulates in the form of humus. A typical feature is the deep penetration, along the profile, of water-soluble organic compounds. At a depth of 60-80 cm the humus content is already 1%-2%. A high water-soluble humus content is in general typical of tundra-gley soils. As a result of the high organic compound content, adsorption capacity is high. The total of adsorbed bases in the top horizons is 50-70 meq per 100 g of soil and in the lower horizons 10-20 meq. Calcium and magnesium are heavily predominant in the composition of the adsorption complex. Unsaturation is very slight (not more than 5%-6%) and is due to adsorbed hydrogen. Owing to the permanent excessive wetting and development of gleyization processes in the mountain-tundra humic surface gley soils, they contain large quantities of mobile iron, which can be extracted with Tamm's extract (up to 1600-2000 mg per 100 g of soil).

The humic surface-gley mountain-tundra soils of the Transbaykal Region accordingly has the characteristic signs of mountain tundra gley soils as described in the case of the Altay-Sayany Region (10, 9), the Far East (6) and the Urals (1): a high content and poor decomposition of organic matter, the presence of water-soluble humus, the presence of a "suspended" gley horizon under the A_0A_1 horizons, a weakly acid reaction, a high adsorption capacity and a considerable amount of mobile iron. The provincial distinctions between these soils are still unknown as they have not been sufficiently studied.

In the natural state the mountain-tundra humic surface gley soils have hardly been used at all for agricultural purposes. On the basis of local farming experience, however, and of the findings of experimental stations in the Far North and Far East, it can be said that after appropriate meliorative measures have been applied the lowland-tundra soils can be used for agricultural purposes as pasture lands, hay lands and, more rarely, plowland (for vegetables). Meliorative work must be directed mainly towards improving the water and heat conditions of the soils. Even one plowing considerably increases the active layer, improves the heat regime, reduces the excessive wetting of the top horizons and raises the content in nutrients.

The usual methods should be applied to improve the heat regime: snow retention, followed by removal of the snow in spring, leaving the stubble in winter and constructing ridges in early spring, mulching and sowing in raised seed-beds. Frost control is an important problem.

The soil nutrition is improved by large non-root applications of mineral and liquid nitrogenous fertilizers in early spring. In choosing an area for fertilizer application, particular attention should be paid to the danger of thermokarst effects.

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CHARACTERISTICS OF THE MICROFLORA OF ARCTIC SOILS

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Information in the literature on the microbial population of USSR polar region soils is extremely limited. It concerns, for the most part, points located no farther north than 70° - 73° north latitude (1, 2, 3, 4). In this paper, we present the results of a study of the soil microflora of Zemlya Franz Josef. We collected the samples a little north of 81° north latitude, in the environs of Nagurskaya on the Zemlya Aleksandra between the 25th and 30th of July, 1955.

Only 13.5% of the surface of Zemlya Franz Josef is not covered with ice and snow, and about one-fourth of this area is found on Zemlya Aleksandra and the western coastal area of Zemlya George. The area free of ice and snow on Zemlya Aleksandra is one of gentle rolling hills, covered with small or with large dark brown gravel, the weathering product of basalts. In some places gravel is variegated because of large amounts of lichens and mosses covering it. There are practically no flowering plants, except for single little flowers of the polar poppy (not more than 2-3 cm high), and the tiny cushion of the violet saxifrage, 5-6 cm in diameter, which on Novaya Zemlya reaches the size of a large bush.

As a result of frost weathering, which is characteristic and quite prevalent in the higher latitudes, basalt, the basic rock on Zemlya Aleksandra develops chiefly medium clay loam fine earths with a neutral reaction and with a considerable admixture of gravel and some organic material, which accumulates with the breakdown of the sparse vegetation. We collected these fine earths partly from the completely bare rocky areas and partly from under mosses, lichens, and polar poppy. After the snow had melted we sometimes found polygonal soils in the depressions between the gravelly hills.

In view of the extreme uniformity of the soils of Zemlya Aleksandra we took only five soil samples for study: Fluvio-glacial glacier drift (sample I), a polygonal soil (sample II), and three kinds of fine earths—from the Barents Sea Coast, which is bare of vegetation (sample III), from under mosses and lichens (sample IV), and from under mosses and lichens and poppy (sample V). We began processing the material immediately after our return to Moscow, i.e., 16 days after the samples were

taken, and then repeated the processing six months later.

Number of Micro-organisms and Their Qualitative Composition

We determined the number of microorganisms in the samples studied by counting the number of colonies cultured on four agar media: 1) protein medium; 2) meat-peptone agar (MPA); 3) synthetic non-protein media of Czapek and Ashby (the latter contains no nitrogen); and 4) a malt agar for culturing fungi. On the basis of data given in Table 1 and microscopic analysis of the colonies, we came to the following conclusions. The fluvio-glacial drift from under the ice dome was sterile. The number of microorganisms (in thousands) cultured on MPA was, in the case of the polygonal soil only (140.0 per 1 g), of the same order as the number of microbes ordinarily found in the middle latitudes in virgin sod-podzolic soils. In the fine earths from under the mosses, lichens, and poppy the number was sharply reduced; in the fine earths taken on the Barents Sea Coast, which is bare of vegetation, the quantity was quite small (37.2 per 1 g). The number of microorganisms grown on synthetic media from polygonal soil was only slightly less than on MPA. Growth was noticeably higher on the non-protein media for the fine earths, especially sample III from the area bare of vegetation. Thus the soils lowest in organic matter were distinguished chiefly by a microflora that did not require protein and to a considerable extent could do quite well without bound nitrogen. Representatives of this microflora were, on the one hand, oligonitrophils¹ (growing on Ashby's medium and forming large mucoid colonies) and on the other hand, mycobacteria (growing well on Czapek's medium, which, as some investigators suggest, can rapidly disintegrate rock.

After the mycobacteria came the non-spore-forming rods. Spore-formers were almost never observed under ordinary conditions of culture at 25°C on MPA. Of all the colonies grown from inoculations of MPA from the five

¹Oligonitrophils are bacteria that can subsist with insignificant quantities of nitrogen in the surrounding medium or can fix it in small amounts.

Table 1

Number (in thousands) and kinds of microorganisms in soils of Zemlya Franz Josef (Nagurskaya, Aleksandra Zemlya) under optimal temperature conditions of growth. Dilution X 10. Samples taken July 27, 1955.

Soil and Sample no.	pH	Bacteria determined by inoculation						Actinomycetes det. by inoculation						Proactino- myces determined by inocula- tion	Fungi de- termined by inocu- lation	Azotob., by methods of dilution, lumps, soil plates
		on MPA			on non-proteinaceous media			on MPA			on non-proteinaceous media					
		Czapek's		Ashby's	Czapek's		Ashby's	Czapek's		Ashby's	Czapek's		Ashby's			
		Colonies per plate	Bacte- ria/g soil	Colonies per plate	Bacte- ria/g soil	Colonies per plate	Bacte- ria/g soil	Colonies per plate	Bacte- ria/g soil	Colonies per plate	Bacte- ria/g soil	Colonies per plate	Bacte- ria/g soil			
Fluvio-glacial drift in low area	5,64	200	0	0	0	0	0	0	0	0	0	0	0	0	0	
Polygonal soil, II	5,67	700	140,0	612	122,4	580	116,0	0	0	0	0	0	1	1200	0	
Fine earths from shore of Barents Sea, lichen vegeta- tion, III	6,28	186	37,2	376	75,2	345	69,0	0	0	0	0	0	5	1,0	0	
Fine earths from under mosses and lichens, IV	6,24	351	70,2	443	88,6	402	80,4	0	0	0	0	0	0	0	0	
Fine earths from under mosses, lichens, and poppy, V	5,97	356	71,2	409	81,8	391	78,2	0	0	16	3,2	7	1,4	8	1,6	

^aFrom the cultural characteristics this colony should be considered as contamination.

Note: Comma represents decimal point.

samples studied, spores were observed in only two colonies. Spore-formers were completely absent on the Czapek and Ashby media. Observations were made for 22 days. *B. mycoides*, *B. cereus*, *B. mesentericus*, and *B. megatherium*, which are common in podzolic soils of middle latitudes, were not observed in the form of colonies typical for them. Thermophilic microorganisms in the same five soils were observed in negligible quantities: one species of white actinomycete and two species of bacteria. They grew at 50°-55°C, but in quantities of no more than one or two colonies per plate with 10-fold dilution. Fungi were not observed. Our earlier observations (7) for soils of high latitudes were similar. Actinomycetes were not found in the polygonal soil, which was richest in organic matter, and they were found in the fine earths, which are almost devoid of organic matter.

The proactinomycete group is often encountered in the high latitudes (Table 1). Azotobacter was not observed in even one sample nor with the use of any standard methods, even though the soil reaction did not exclude their growth. The number of bacterial antagonists for azotobacter in soils of Zemlya Franz Josef (Table 2) was small, and, in comparison with sod-podzolic soils of Chashnikov (Moscow region, Agricultural Biology Station of Moscow State University), can be considered insignificant.

By the same token, experiments with the survival of azotobacter, inoculated into soil of Zemlya Franz Josef, showed that the microorganism survives for no more than 4-9 months. It is quite probable that in this case the death of the azotobacter is caused by the depletion of available nutrients, which are found in extremely small quantities in these soils and are not restored under the artificial conditions of experiment.

The observed data posed a number of questions for us, the solution of which required a large number of experiments. It was of interest to find out the temperature best suited for the growth of microorganisms living in the soil of high latitudes and the limiting temperatures for their vital activity. We focused our attention on the unexplained fact of the almost complete absence of spore-forming bacteria in the soils studied, even though many of the bacterial colonies which developed when these were inoculated into nutrient media could be classified as spore-formers on the basis of their external appearance and the morphological characteristics of the cells. This phenomena, which we noticed in our studies of the soils of Novaya Zemlya (7), was even more marked in the soils of Zemlya Franz Josef.

Finally, we are not uninterested in finding out the fate of *B. mycoides*, *B. cereus*, *B. mesentericus*, and *B. megatherium*, which are widely distributed in the middle latitudes and either absent or assume atypical cultural characteristics under the ecological conditions of the Arctic.

Temperature Conditions Attending Development of the Microorganisms

We made the following experiments: MPA

inocula of the soils under study were held in thermostats at temperatures of +3° to +60° C². The colonies that grew on the plates were counted and from the largest numbers we determined the temperature range within which the growth was most intense. This number was provisionally assumed as an index of 100% growth. Then we calculated the percent of this number of colonies corresponding to the number of colonies that grew under less favorable temperature conditions. On the basis of the data obtained, we compiled Tables 3 and 4.

From Table 3, we can see that for the soils of Zemlya Franz Josef, the temperature range of optimal growth of microorganisms is rather narrow; it ranges between 15° and 25°C. There is a rather sharp decline in the growth intensity on both sides of this range. At +3°C, the number of colonies that grow amounts to no more than 2%-12.1% of the maximum number developing at the optimal temperature, and often growth is inhibited completely, but when it occurs, no less than 35 days are required for it to begin.

At temperatures above 25°C, the decline in growth intensity is even more rapid, and at 32°C the growth is practically stopped and only very rarely do isolated colonies develop at 34°C. The nature of the variations with temperature in the case of the sod-podzolic soils of Chashnikov is somewhat different (Table 4). The region of optimum growth of microorganisms was considerably wider, extending from 20°-34°C. The growth did not markedly decline even at 36°-38°C (soil from a forest). A marked decline was observed only at 34°C, and sometimes even at 50°-55°C; thermophilic forms continued to grow up to 60°C. In the virgin soil studied they were rare; they are more common in cultivated soils. As regards low temperatures, the 3°C growth intensity amounted to 4.4%-12.3% of the optimum, after 25 days.

Thus the temperature optimum for growth of microorganisms both of Arctic and middle latitudes initially is similar with small variations—in the range 15°-20°C. But for microorganisms of the Moscow area the optimum is extended in the direction of temperatures higher than 25°C. It follows from this that the microorganisms of the Arctic, apparently, are not specifically adapted to the low-temperature conditions of their habitat. The low temperatures do not favor their growth, but, on the contrary inhibit it. Similar data for the microflora of the polar soils have been given by Rybalkinaya (6).

These data are also presented in the form of a somewhat simplified, generalized diagram (Fig. 1).

An experiment similar to that just described was carried out in test tubes with bacterial strains derived from the same inocula used in the previous experiments. The results are presented graphically (Fig. 2). Almost all the strains isolated from the soils of Zemlya Franz Josef grow at temperatures of 3°-30°C. A marked decline in growth begins at 32°C. Almost all the strains from sod-podzolic soils of Chash-

²For want of cooling equipment, it was unfortunately necessary to omit temperatures below +3°C.

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Table 2

Antagonism for azotobacter of bacterial strains isolated from soils of Zemlya Franz Josef and sod-podzolic soils of Chashnikovo

Soil and Sample no.	pH	Total no. of strains of spore-forming and non-spore-forming bacteria	Strains		% antagonists
			Antagonists	Non-antagonists	
Polygonal soil II. ZJF ^a	5,67	39	14	25	35,8
Fine earth III. ZFJ ^a	6,28	22	8	14	36,4
Fine earth IV. ZFJ	6,24	29	8	21	27,6
Fine earth V. ZFJ	5,97	40	17	23	42,5
Sod-podzolic from forest. Chashnikovo	5,4	59	48	11	81,3
Sod-podzolic under clover. Chashnikovo	5,6	43	42	1	97,7

^a ZFJ — Zemlya Franz Josef.

Note: Comma represents decimal point.

nikov grow well between 10° and 38°C. They do not grow as well at 3°C as strains isolated from the soils of Zemlya Franz Josef. Similarly, in the case of Chanikov strains, appreciable reduction in growth at higher temperatures begins not at 32°C, but at 40°-43°C. The curves in Figure 2 show that the optimum temperature for growth of these and the other strains is almost or entirely the same, but that the range of optimum temperatures for growth of strains from the sod-podzolic soils of Moscow region is wider and extends to 34°-38°C, when the intensity of the growth of a large part of the strains from the Zemlya Franz Josef soils is markedly reduced—to the point of almost complete cessation. Below 10°C the survival of Chashnikov strains drops rather markedly, while the growth intensity of the strains from Zemlya Franz Josef changes little.

Spore-Formation

Some authors (5) indicate that northern soils are low in bacilli. This was also our first impression when we began our work with materials collected in Novaya Zemlya and later Zemlya Franz Josef. But a more detailed study of the Novaya Zemlya soils (as a result of which we succeeded in converting a few strains of non-spore-formers isolated from them into typical spore-formers) has made it possible for us to state (7) that under Arctic conditions many bacteria, apparently, live with their cells in the vegetative state. They frequently lose their ability to form spores, but we have succeeded in some cases in restoring this artificially. The soil samples from Zemlya Franz Josef made it possible for us to extend these observations and to confirm them on new material collected at appreciably higher latitudes.

When we inoculated soils from Zemlya Franz Josef into the media—MPA, Czapek, and Ashby's—we also obtained a large number of colonies, which in external appearance resembled spore-forming bacteria. But we were not able to observe spores in them, except for two colonies grown on MPA inoculated from two types of fine-earths (samples III and IV), which formed spores from the very beginning at all temperatures (strains III/1 and IV/2 [see Table 5]). Since our experiments with the soils of Novaya Zemlya showed that spore-formation can be effected most successfully with artificial temperature influences, in our work with the soils of Zemlya Franz Josef we almost completely discarded transfers to media of different compositions and grew our cultures directly at different temperatures from +3° to +60°C. For this purpose, in addition to the two strains mentioned previously, we selected 53 more strains isolated on various media (MPA, Czapek's, and Ashby's), of which 36 were particularly "suspect" as regards similarity to typical spore-forming bacterial species. The strains were isolated from the following soils: the polygonal soil (sample II), 15 strains; the fine-earth from the shore of the Barents Sea which was devoid of vegetation (sample III), 10; the fine-earth from under moss and lichens (sample IV), 15; and the fine earth from moss, lichens and poppy (samples V), 15 strains.

Depending on the effect observed, we increased the period of this or that temperature exposure to 60 days. In this way we succeeded in artificially causing spore formation in four strains (II/1, II/3, III/2, and III/3)³ of the 53

³ In the designation of the strains, the number of the soil sample was placed in the numerator, and the serial number of the strain in the denominator.

Table 3

Growth of bacteria (in thousands) on Petri dishes of MPA inoculated with samples of soils from Zemlya Franz Josef, at different temperatures. Dilution X 10.

Temperature, °C	Polygonal, II			Fine earths, III			Fine earths, IV			Fine earths, V		
	No. of colonies	No. of bacteria/g soil	Ratio, %	No. of colonies	No. of bacteria/g soil	No. of colonies	No. of colonies	No. of bacteria/g soil	No. of colonies	No. of colonies	No. of bacteria/g soil	No. of colonies
3	14	2,8	2,0	0	0	0	0	0	0	44	8,8	12,1
10	230	46,0	32,8	88	16,0	46,7	121	24,2	34,5	200	40,0	55,0
15	453	90,6	64,6	164	32,8	85,9	153	30,6	43,6	364	72,8	100,0
20	701	140,2	100,0	191	38,2	100,0	351	70,2	100,0	178	35,6	48,9
25	415	83,0	59,3	134	26,8	70,1	388	77,6	100,0	118	23,6	32,4
28	220	44,0	31,4	28	5,6	14,7	183	36,6	52,1	65	13,0	17,8
30	122	24,4	17,4	8	1,6	4,2	42	8,4	12,0	56	11,2	15,4
32	2	0,4	0,3	1	0,2	0,5	1	0,2	0,3	5	1,0	1,4
34	0	0	0	1	0,2	0,5	0	0	0	5	1,0	1,4
36	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0

Note: Comma represents decimal point.

Table 4

Growth of bacteria (in thousands) on Petri dishes of MPA inoculated with sod-podzolic soils (Chashnikovo), at different temperatures. Dilution X 10.

Temperature, °C	Sod-podzolic from forest			Sod-podzolic under clover (cultivated but not fertilized)		
	No. of colonies	No. of bacteria/g soil	Ratio, %	No. of colonies	No. of bacteria/g soil	Ratio, %
3	28	5,6	4,4	74	14,8	12,3
10	315	63,0	49,2	332	66,4	56,8
15	401	80,2	62,7	419	83,8	70,6
20	653	130,6	100,0	478	95,6	80,5
25	687	137,4	100,0	604	120,8	100,0
28	651	130,2	100,0	650	130,0	100,0
30	528	105,6	100,0	530	106,0	100,0
32	624	124,8	100,0	470	94,0	79,1
34	613	122,6	100,0	426	85,2	71,9
36	477	95,4	74,5	293	58,4	49,1
38	450	90,0	70,3	267	53,4	45,0
43	8	1,6	1,3	68	13,6	11,4
50	2	0,4	0,3	47	9,4	7,9
55	1	0,2	0,15	22	4,4	3,7
60	0	0	0	5	1,0	0,8
70	0	0	0	0	0	0

Note: Comma represents decimal point.

studied in the experiments (Table 5).

It is apparent from Table 5 that it was possible to induce spore formation artificially in two strains of the 15 isolated from the polygonal soil II with exposure to temperatures from 28°-36°C, and in two strains of the 10 isolated from fine earth III at temperatures from 32°-36°C. At the same time only two strains form

spores three to four days after being held at the corresponding temperature. In all the rest, spore formation began with a long time lag of 14-48 days, depending on the temperature conditions of culture. It should be mentioned that the experiments with artificially produced spore formation gave positive results only on MPA but not on Czapek's and Ashby's media.

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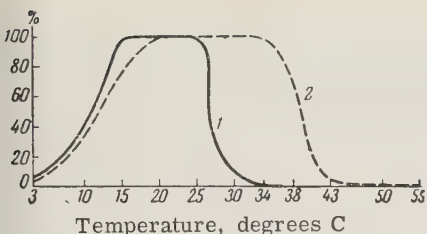


Fig. 1. - Growth intensity of micro-organisms on Petri dishes of MPA at different temperatures.

1 - Soil from Zemlya Franz Josef; 2 - Sod-podzolic soil from a forest, Chashnikovo, Moscow Region.

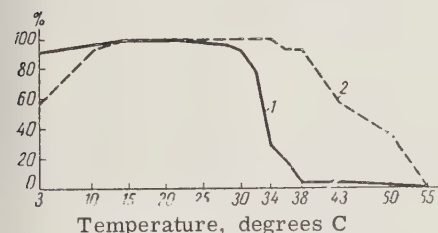


Fig. 2. - Number (in %) of strains growing at various temperatures.

1 - soil from Zemlya Franz Josef; 2 - Sod-podzolic soil from a forest, Chashnikovo, Moscow Region.

Thus of the 55 strains studied, two were spore-formers from the very beginning and it was possible to induce spore-formation artificially in four. Low temperatures ($+3^{\circ}\text{C}$) did not produce spore-formation. On the contrary, under these conditions spore-formation was not observed even in the strains from the Zemlya Franz Josef soils for which spore-formation had been induced artificially at higher temperatures. At a temperature of $+3^{\circ}\text{C}$ spore formation persisted only in two strains, III/1 and IV/2, which in general was natural.

Four strains, in which it was possible to induce spore-formation artificially, we kept for a year, and then checked to find out whether they retained their artificially induced property of forming spores. At the beginning of the experiments one strain was accidentally lost, but the other three began to produce spores after the normal interval—3-4 days at temperatures of 3° - 36°C , as did strains III/1 and IV/2, which did not lose this property.

Thus we were able to restore the bacteria isolated from the soils of Zemlya Franz Josef to their normal growth cycle which they had lost under the particular conditions of the Arctic.

Parallel to the experiments described, we conducted (for purposes of comparison) experiments with 14 strains of bacteria from sod-podzolic soils of Chashnikov. We are led to conclude from Table 6 that at a temperature of $+3^{\circ}\text{C}$ the strains isolated for the most part do not grow, and if they grow, they do not produce spores. Intense spore-formation was observed

Table 5

Spore formation at different temperatures and after different intervals (in days) for 55 bacterial strains isolated from soils of Zemlya Franz Josef^a

Strains ^b	3°	16°	20°	25°	28°	30°	32°	34°	36°	38°	43°	50°	55°
II 1	—	—	—	—	+(38)	+(15)	0	0	0	0	0	0	0
II 3	—	—	—	—	—	+(40)	+(48)	+(4)	+(14)	0	0	0	0
III 1	+(10)	+(3)	+(3)	+(4)	+(3)	+(4)	+(5)	+(14)	+(4)	+(3)	+(7)	+(7)	0
III 2	—	—	—	—	—	—	+(3)	+(4)	+(14)	0	0	0	0
III 3	—	—	—	—	—	—	+(3)	0	0	0	0	0	0
IV 2	+(10)	+(3)	+(3)	+(2)	+(38)	+(40)	+(45)	+(35)	+(5)	0	0	0	0
Other 49 strains	—	—	—	—	—	—	0	0	0	0	0	0	0

^aLegend: +, spores formed; —, spores not formed; 0, no growth; numbers in parenthesis are the intervals in days after which spores formed.

^bNumerator — number of soil sample; denominator — serial number of strain.

Table 6

Spore formation at different temperatures and after different intervals (in days) for 14 bacterial strains isolated from sod-podzolic soils of Chashnikov

Strain	Land use	3°	20°	25°	28°	30°	32°	34°	36°	38°	43°	50°	55°
101 4	Cultivated	—	—	—	—	—	—	—	—	+(10)	—	0	0
102 1	Same	0	+(5)	+(3)	+(2)	+(1)	+(1—2)	+(2)	+(7—8)	+(20)	+(20)	0	0
103 1	"	0	+(5)	+(1)	+(2)	+(2)	+(3)	+(1)	+(3)	+(2)	+(2)	+(2)	0
105 4	"	0	+(14)	+(3)	—	—	+(2)	+(5)	+(4)	+(4—6)	—	0	0
107 1	"	—	+(5)	+(3)	+(1)	+(1)	+(1)	+(1)	+(2)	+(2)	0	0	0
107 4	"	0	+(6)	+(1)	+(2)	+(2)	+(1—2)	+(2)	+(3)	+(3)	+(2)	+(2)	0
107 5	"	—	—	—	—	—	—	—	—	—	0	0	0
108 1	"	—	—	—	—	—	—	—	0	0	0	0	0
114 5	"	—	+(5)	+(6)	+(2)	+(2)	+(14)	+(15)	+(20)	+(14)	0	0	0
116 4	"	—	—	—	—	—	—	—	—	—	0	0	0
116 5	"	—	—	—	—	—	—	—	—	—	—	0	0
124 5	"	—	—	—	—	—	—	—	—	—	0	0	0
68	Clear-cut of forest	0	+(1)	+(2)	+(2)	+(2)	+(1)	+(2)	+(1)	+(1)	+(1)	+(1)	0
85	Reforested area	0	+(1)	+(2)	+(2)	+(2)	+(1)	+(1)	+(1)	+(1)	+(1)	+(1)	0

Legend: +, spores formed; —, spores not formed; 0, no growth; numbers in parenthesis are the intervals in days after which spores formed.

^aStrains were obtained from L. N. Stepanova of Agricultural Biological Station at Chashnikov.

beginning with a temperature of 20°C in eight strains. One strain began to form spores only at 38°C, and five strains appeared to be non-spore-formers.

This experiment was broadened in the following way: the inoculated plates were stored at a

temperature of +3°C for two weeks. Spore-formation did not begin. Then the plates and seven strains inoculated from them into test tubes were placed in a thermostat at 25°C. All the strains formed spores: one on the third day, three on the fourth day, one on the seventh day, and two more after three weeks. Spore-

mation began in exactly the same way in the colonies on the plates.

We also studied the temperature conditions at were most favorable for the development of the process of forced spore-formation in such classical spore-forming species as *B. mycoides* and *B. cereus*, which are numerous in sod-podzolic soils. It was shown that spore-formation proceeds most rapidly in these forms only under temperature conditions that coincide with the optimal for growth of these bacteria. Between 20° and 36°C almost all the colonies on the plates produced spores. Both higher and lower temperatures inhibit spore-formation. At 10°C the process hardly takes place. Of 19 colonies of *B. mycoides* under these conditions, only one formed spores, and of 15 colonies of *B. cereus*, no spores at all were formed. At 15°C the intensity of spore-formation increases. In *B. mycoides*, of 23 colonies, spores were observed in 13, and in *B. cereus*, of 17 colonies, spores were observed in two. At a temperature of 32°C, the intensity of the process tapers off sometimes until complete cessation, and at 34°C we generally did not observe spore-formation. The cells then lose their normal appearance at this time and assume a degenerative character. At 36°C, just as at +3°C, the growth of *B. mycoides* and *B. cereus* is strongly inhibited or even ceases.

Thus in our experiments spore-formation ceased when it appeared from the more general viewpoint that the organism needed it most. Spore-formation slowed down, and then ceased completely until as a result of the effect of higher or lower temperatures the cells began to undergo degenerative changes and then their growth also ceased completely. On the other hand the process was initiated and developed rapidly as soon as we placed the cell into favorable conditions.

Conclusions

The ecological conditions for the existence of microorganisms at the high latitudes of the Arctic are quite different from those observed not only in the middle latitudes but also in the northern latitudes.

The material in which soil is beginning to develop here, be it rock or drift deposited by glaciers, is not always supplied with organic material and nitrogen. This, to a considerable extent, determines the number and types of the bacterial population that develops under these conditions. In the Arctic a leading role is played by the mycobacteria, which, as we surmise, are able to disintegrate rock. Non-spore-forming rods grow in large numbers. We also find oligonitrophils, proactinomycetes, and, as a general rule, actinomycetes are encountered in small numbers, but on Novaya Zemlya they are often observed in massive quantities. Fungi have not been observed in Arctic soils.

It might seem that the constant low temperatures and frozen ground in the high Arctic should have produced microbial cenoses specially adapted to these severe conditions of life and better able to grow at low temperatures. But all the observations made by us indicate that the

temperature optimum for the growth of microorganisms differs little here from the natural soil population of the middle latitudes. At the low temperature of +3°C the microorganisms from both Zemlya Franz Josef and the sod-podzolic soils of Moscow area show poor growth to almost the same degree. But the limit of growth at temperatures above 20°C is lower for microorganisms living at high latitudes than for microorganisms of the central zone of the USSR. For the microorganisms of the Arctic soils the limiting temperatures are 32°-34°C. Above 32° only isolated colonies of "Arctic thermophils" grow. In the case of microorganisms of virgin sod-podzolic soils from forests in Moscow region we observe almost complete cessation of growth at 43°C. At a temperature of 43°C, the typical thermophils grow, which are almost non-existent in the soils of Zemlya Franz Josef. In cultivated soils, which are richer in them, single colonies of thermophils grow even to a temperature of 60°C.

A characteristic feature of high latitude microbes is the slow rate of development with each temperature. They were usually 7-10 days behind in development as compared with bacteria from Moscow soils.

One biological characteristic of the bacterial population of the high-latitude Arctic is of extremely great interest, namely: the very widespread tendency to lose the ability to form spores.

The data presented in this paper and similar data published earlier by us on the soils of Novaya Zemlya indicate that low temperatures slow down or even stop spore-formation. This applies equally to soils of both Arctic and middle latitudes. But under Arctic conditions the effects of low temperatures, which are more or less continuous, lead often to a complete cessation of this process. As a result there is a secondary emergence of non-spore-forming types from spore-forming bacteria. We have been led to this conclusion both by cultural characteristics and by morphological features of these Arctic forms, as well as by experimental data, which indicate that in some cases it is possible to induce spore-formation artificially and, consequently, to restore to the bacterial cell the capacity to form spores which it had lost.

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ROLE OF IMPROVEMENT CUTTINGS IN RAISING FOREST SOIL FERTILITY

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Changes in soil conditions under the influence of forest management practices are of great importance for the growth and development of forest vegetation. The necessity of understanding these changes in the properties and fertility of the soil is obvious. One of the most widely recommended methods of good forest management is improvement cutting (1, 2, 3, 4). Insufficient study, however, has been devoted to the effect of such cuttings on the forest soil properties, and in the case of aspen stands there has been no research at all.

In 1955, the forest soil science laboratory of the Voronezh State University began research to study the influence of improvement cuttings in aspen plantations on the forest soil properties in the southern part of the forest steppe (Usman' pine forest). The observations were made in two experimental areas in 30- and 55-year-old aspen stands with sedge, situated on ground of similar relief in each case, on a gentle slope from the Voronezh-Usman' watershed to the Usman' River.

The soil here is grey-brown forest clay loam on well graded old alluvial fine and medium quartz sand underlain by a clay-silty clay loam to a depth of 100-170 cm.

Two profiles were chosen for investigation

from each of the experimental areas: one in which improvement cuttings had been performed, the other, as a control, with no cuttings.

A 30-year-old aspen stand (compartment No. 462): site quality I. Density 0.75. Improvement cuttings in 1952. Number of trees per hectare 1,688.² A control section was chosen from an aspen stand of the same age and site quality in the neighboring compartment No. 463 where the density is 1.0 and the number of trees per hectare 2,460.

A 55-year-old aspen stand (compartment No. 463): site quality I. Density 0.8. Improvement cuttings in 1940-1942. Number of trees per hectare 988. An aspen stand close by where there had been no improvement cutting was selected for control (site quality I. Density 1.1. Number of trees per hectare 1464).

After cutting and removal of some of the trees a more open stand was obtained for the remaining trees, with the result that the lateral branches, crowns and leaf mass developed better. Study of the forest litter-fall over a 4-year period showed that the amount increased in those areas which had improvement cutting to a density of 0.75-0.8 (Table 1).

¹The work was done under the direction of Prof. N. Remezov.

²Tree count by M. P. Skryabin (1957).

Table 1
Amount of litter-fall (kg per ha, air-dry weight)

Plantation	Density	Year			
		1955	1956	1957	1958
30-year-old aspen stand	0,75	5344	4989	5820	5611
	1,0	4769	4921	4845	4889
55-year-old aspen stand	0,8	4977	5254	4756	5185
	1,1	4131	4333	3821	4684

Note: Comma represents decimal point.

Table 2

Nitrogen and ash element uptake with litter-fall, by years, kg per ha

Plan- ta- tion	Dens- ity	N				P ₂ O ₅				K ₂ O				CaO			
		1955	1956	1957	1958	1955	1956	1957	1958	1955	1956	1957	1958	1955	1956	1957	1958
30-year- old aspen stand	0,75	44	45	48	46	29	29	34	34	69	67	81	79	168	159	188	184
55-year- old aspen stand	1,0	42	43	43	44	28	28	28	28	63	62	61	61	154	153	150	152
30-year- old aspen stand	0,8	42	44	43	44	18	19	18	19	60	60	58	62	153	154	158	159
55-year- old aspen stand	1,1	37	37	33	39	17	16	14	17	50	50	47	59	134	128	148	145

Note: Comma represents decimal point.

The increase in the volume of litter fall was due to the increased leaf mass of the aspens and the accelerated rate of development in the Norway maple undergrowth.

By creating a large mass of organic matter the aspens with improvement cuttings added larger quantities of ash elements and nitrogen into the biological circulation. As Table 2 shows, larger amounts of nitrogen, calcium, potassium and phosphorus are returned to the soil with the litter-fall in the thinned plantations. The calcium uptake with the litter-fall is greatest (128-188 kg per ha), the potassium and nitrogen uptake lowest (47-81 and 33-48 kg per ha, respectively). Even less phosphorus is returned to the soil with litter (28-34 kg per ha) in the 30-year-old aspen stand and 14-19 kg per ha in the 55-year-old plantation. Table 3 shows how much more nitrogen and ash elements (in kg per ha, averaged over 4 years) enter the soil in the areas where improvement cutting has been practiced than in the control areas.

Thinning the tree stand increases the amount of light and heat reaching the soil, making for better development of the herbage under the aspen canopy.

Research over a period of 3 years has shown that in the improvement cutting areas the total amount of organic matter synthesized in the above-ground parts of the herbage during the

growing period is a great deal larger than in the stands where there has been no improvement cutting. As we see in Table 4, the total amount of organic matter in the above-ground parts of the herbage is 50-198 kg per ha more in the thinned 30-year-old stand than in the control area. The difference is far smaller in the case of the two 55-year-old stands, where improvement cutting had been carried out 10-12 years earlier, and the undergrowth had meanwhile developed strongly to form a dense canopy, preventing the growth of a grass cover. The increase in the organic mass of grass litter was due mainly to the growth of sedge, particularly pilose sedge, which differs by its high potassium content.

The results obtained by converting the nutrients drawn into biological circulation by the herbage into kg per ha (Table 5) showed that a larger amount of plant nutrients reached the soil in the thinned aspen stand than in the control plots. The high potassium (8-25 kg per ha) and nitrogen (6-19 kg per ha) content in the grass litter deserves attention. Phosphorous content is lowest (1-3 kg per ha), calcium content intermediate (3-8 kg per ha).

The soil in the 30-year-old aspen stand where improvement cutting was practiced received a far greater quantity of mineral substances with the grass litter than that of the 55 year-old aspen stand.

Table 3

Influence of improvement cuttings on N and ash element uptake

Plantation	Density	CaO	K ₂ O	N	P ₂ O ₅
kg per ha					
30-year-old aspen stand	0,75	22,5	12,25	2,75	3,5
	0,8	17,3	8,5	6,75	2,5
increase as % of control					
55-year-old aspen stand	0,75	14,8	19,8	6,4	12,5
	0,8	12,4	16,5	18,3	15,6

Note: Comma represents decimal point.

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Table 4

Amount of grass litter, kg per ha

Plantation	Density	Year		
		1955	1957	1958
55-year-old aspen stand	0,75	485,4	471,5	638,5
	1,0	286,5	291,1	588,6
30-year-old aspen stand	0,8	293,2	241,8	402,6
	1,1	201,5	225,0	543,0

Note: Comma represents decimal point.

Table 5

N and ash element uptake from above-ground part of grass cover, by years, kg per ha

Plantation	Density	N			P ₂ O ₅			K ₂ O			CaO		
		1955	1957	1958	1955	1957	1958	1955	1957	1958	1955	1957	1958
30-year-old aspen stand	0,75	15,41	13,14	19,27	2,68	2,36	3,40	20,33	17,60	25,55	6,27	5,95	8,17
	1,0	9,41	9,05	17,55	1,62	1,58	3,10	12,36	11,97	23,31	3,72	3,65	7,51
55-year-old aspen stand	0,8	9,26	7,39	11,58	1,62	1,30	2,06	12,21	9,79	15,45	3,78	3,10	5,10
	1,1	6,78	6,26	16,30	1,17	1,12	2,88	8,9	8,37	21,63	2,64	2,84	6,94

Note: Comma represents decimal point.

Table 6 shows the amount of nitrogen and ash element (in kg per ha) reaching the soil with the grass litter in the improvement cutting areas as compared with the control areas.³

Comparing Tables 3 and 6 we find that more nitrogen is returned to the soil with the grass

litter in the 30-year-old aspen stand where improvement cutting was practiced, as compared with the control plot, than with the tree litter, but slightly less potassium. This means that 3 years after thinning, the herbage begins to exert a considerable influence on the biological circulation of nutrients under the aspen canopy. Thirteen years later, however, as can be readily seen from the example of the 55-year-old aspen stand, the influence of the grass cover in enriching the soil with mineral elements in the thinned stands is fading out.

³ Averages for 3 years in the case of the 30-year-old and for the years 1955 and 1957 in the case of the 55-year-old aspen forests.

Table 6

Increase in N and ash element in improvement cutting areas

Plantation	Density	CaO	K ₂ O	N	P ₂ O ₅
kg per ha					
30-year-old aspen stand	0,75	5,28	3,94	1,88	0,71
	0,8	2,39	1,7	0,7	0,32
increase as % of control					
55-year-old aspen stand	0,75	33,2	32,8	37,9	33,8
	0,8	27,4	25,6	25,5	28,0

Note: Comma represents decimal point.

Table 7

Chemical properties of soil (averaged for two growing periods, May-October, 1957 and 1958)

Plantation	Density	Humus %	N	P ₂ O ₅	K ₂ O	Ca	NO ₃	NH ₄	pH	
			mg per 100 g of soil						Water	Salt
30-year-old aspen stand	0,7	4,56	7,28	3,96	8,16	110,4	2,7	6,26	6,8	6,0
	1,0	3,33	4,66	2,83	7,00	101,3	1,51	7,5	6,0	5,5
55-year-old aspen stand	0,8	4,98	8,10	5,00	12,00	156,6	3,0	4,45	6,9	5,9
	1,1	4,44	5,50	3,10	10,00	123,0	2,62	5,7	6,3	5,6

Note: Comma represents decimal point.

Table 8

Water-physical properties of soil

Horizon	Depth, cm	Specific gravity		Total porosity	Maximum hygro-scopicity	Total field moisture capacity
		Solid phase	Bulk density			
30-year-old stand with improvement cutting						
A	2—10	2,53	0,86	66,00	3,84	47,98
A/B ₁	10—20	2,56	1,21	52,72	1,68	19,05
30-year-old stand without improvement cutting						
A	2—10	2,58	0,95	63,18	3,33	42,00
A/B ₁	10—20	2,62	1,24	52,67	1,29	17,60
55-year-old stand with improvement cutting						
A	2—10	2,58	0,96	62,79	3,0	42,53
A/B ₁	10—20	2,59	1,21	53,28	1,11	16,90
55-year-old stand without improvement cutting						
A	2—10	2,52	1,08	57,14	3,0	39,85
A/B ₁	10—20	2,57	1,28	50,19	1,07	13,47

Note: Comma represents decimal point.

After calculating the amount of nitrogen and ash elements reaching the soil annually with the tree and grass litter in the improvement cutting areas, we obtained the following values for the 30-year-old aspen stand: calcium—24.3 kg per ha; potassium—17.53 kg per ha; nitrogen—6.69 kg per ha; phosphorus—4.21 kg per ha; and the following values for the 55-year-old stand: calcium—17.07 kg per ha; potassium—10.9 kg per ha; nitrogen—8.45 kg per ha; phosphorus—2.82 kg per ha.

From these data it follows that the biological circulation of elements is greatly intensified as a result of improvement cutting in the aspen stands. The fact that different amounts of mineral elements are drawn into the biological circulation leads to a difference in the action of the aspen stands on the soil, its properties and

fertility. Table 7 shows the changes in the chemical composition of the soil in the humus-accumulative horizon (2-10 cm) under the influence of improvement cutting.

The humus content in the soils in the thinned stands increased by 1.23% in the 30-year-old stand and 0.5% in the 55-year-old stand. The amount of readily-hydrolyzable nitrogen compounds and available phosphoric acid appreciably increased in the soils in areas where improvement cutting had been practiced. The exchangeable calcium and potassium content also increased. The pH measurements in salt and water suspensions indicate that the active acidity of the soil is slightly reduced as a result of improvement cuttings. The amount of nitrate nitrogen in the soils of the thinned stands increased, but not appreciably. The highest con-

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Table 9

Moisture contents, mm per soil meter depth

Plantation	Density	Year			
		1955	1956	1957	1958
30-year-old aspen stand	0,75	422	489	446	544
	1,0	412	479	409	538
55-year-old aspen stand	0,8	446	503	373	566
	1,1	391	471	331	544

Note: Comma represents decimal point.

ent in ammonium nitrogen was detected in the reas where no improvement cutting had been racticed, a phenomenon which can apparently e explained to the more intensive oxidation of mmonium nitrogen into nitrates in the soils of he thinned areas.

Improvement cutting, then, resulted in im- rovement of the forest vegetation for the top, umic horizon: the humus content increased, nd so did the content in the most important ineral plant nutrients—nitrogen, phosphorus, otassium and calcium.

Investigations into the chemical properties f the root layer at depths of 10-20 cm and 20- 0 cm in A/B₁ and B₁ horizons also revealed he soil improving influence of improvement utting. The change in chemical composition nd in particular the increased humus content in he soils of the thinned areas was reflected in he water-physical properties (Table 8) as a re- uction of bulk density (apparent specific gravi- y according to the old terminology), increased otal porosity and increased water retention apacity; in other words it had a favorable ef- ect on the properties of sandy soils.

Four years study of the water regime showed hat in the growing period (May-October) the oisture contents in the top meter layer of the oil were higher in the thinned than in the con- trolled areas (Table 9).

Conclusions

1. Improvement cutting at the optimum rate (to a density of 0.75-0.8) in aspen stands of the forest steppe zone leads to certain changes in the biological circulation of elements under the forest canopy. The soil in the thinned areas re- ceives appreciable amounts of dead organic mat- ter in the form of tree and grass litter, 92% of which is from the trees.

2. The increased litter-fall in the thinned stands increases the amount of nutrients reach- ing the soil with the litter. The values for chemical analysis of the soil indicate increased calcium, potassium, phosphorous and nitrogen content in the soil, and improved physical and water properties of soil.

3. Forest soil fertility is thereby improved, as are the forest vegetative conditions, which are of great importance both as regards the in- crement and quality of the aspen stand and also in regard to the replacement of the aspens by other tree species which, though long-lived and resistant, make greater demands on the soil.

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NITRATE CHANGES ASSOCIATED WITH THE RELIEF AND EROSION OF SOILS

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The Bashkir Republic occupies a broad territory of the southern Ural forest steppe and steppe zone. The environmental conditions in this territory are quite variable. Dry steppe areas are included along with mountain areas with a short growing season and excessive moisture. The relief is quite broken. More than 75% of the cultivated land is situated on slopes of varying steepness and exposure. The soils and vegetation are also characterized by great diversity. All this, as well as the type of land use, favors the development of wind and water erosion in many areas of the Republic (1, 2, 3). Wind and water erosion of soils brings enormous losses to agriculture. Destroying soil fertility on large areas, they sharply reduce the yields of agricultural crops.

One method of restoring lost fertility to these soils is proper fertilization, but it must not be uniform where individual regions have dissected relief with varying soils. It is necessary to know the nutrient status of the soils in different elements of the relief, considering their degree of erosion, in order to establish proper use of local and mineral fertilizers.

The question of nutrient status in great soil groups and soil types has been thoroughly studied for level relief (2). This question has been studied very little for eroded areas in relation to separate elements of relief. Such studies have not previously been made for the leached chernozems of the Bashkir Ural foothills.

In order to discover the effects of erosion on the content of one of the more soluble plant nutrients, we observed nitrate changes in fallowed fields on different elements of relief from 1951 to 1953. Nitrates were determined in duplicate by the method of Grandval'-Lyazho. The soil samples were composited from nine cores taken from each investigated area with a soil auger. The work was carried out in the educational establishment of the Bashkir Agricultural Institute. The areas under study were situated on the lower, middle, and upper portions of sigmoid slopes facing north or south, and on the ridge. The soils were noticeably eroded on the upper and middle slopes, and showed deposition on the lower slopes. Soils on the ridge have not been subjected to erosion, but erosion is developing quite strongly at present. The average soil erosion was 10.5-22.0

metric tons per hectare on the upper slopes, and 22.1-42.5 metric tons per hectare on the middle slopes. On the other hand, soil deposition was 22.5-32.5 metric tons per hectare on the lower slopes. As a result, the soils of the investigated areas differed somewhat in several characteristics (Table 1).

From Table 1 it may be seen that the soil changes markedly with relief. Soil erosion, caused mainly by melt water, begins on the upper slope, is strongest on the steep middle parts, tapers out and changes to accumulation with decreasing slope.

Relief also influences the soil water regime. In Table 1 it is shown that the water content in soil decreases with distance from the divide, reaches a minimum at the middle of the slope, but increases greatly at the foot of the slope. The north slopes are characterized by a relatively greater moisture content.

It is known that the soil temperature regime also depends on the surface relief and exposure. Variations in a number of physical and chemical soil properties (moisture, humus content, structure, temperature, etc.) cause diverse development of nitrification on different elements of relief (Table 2).

At all times, the lowest nitrate contents on the slopes were observed in the eroded soils. The nitrate content decreased with distance from the divide and increasing soil erosion, but it increased sharply again in the deposited soil at the foot of the slope.

Usually, the greatest nitrate contents were observed in the plow layer, with considerably less below the plow layer. But at times on some parts of the slope, nitrates were greater below the plow layer. This was observed, for example, on April 27 and June 7, 1952 (after rains), on the lower slopes and the divide. Apparently this is caused by leaching from the upper layer, which is more pronounced on relatively level areas, where there is no runoff of rainwater.

On all areas, the nitrate changes in the 0-40 cm layer followed the same trends. They were somewhat different in the 40-60 cm layer. While the greatest nitrate contents in the plow layer were found on the lower south slope, in the 40-60 cm layer they were usually greater on the

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Table 1

Characteristics of the soils on the experimental areas

Property measured	Parts of the south slope			Ridge	Parts of the north slope		
	Lower	Middle	Upper		Lower	Middle	Upper
Slope, degrees	1,0	5,0	2,5	0,0	0,0	2,5	1,5
Thickness of A horizon, cm	78	39	47	56	93	50	52
Humus content, %:							
Ap	15,21	11,79	12,20	13,47	12,99	10,87	11,02
A ₁	11,56	9,15	10,35	11,36	12,84	9,69	10,27
Aggregates >0.25 mm in diameter in plow layer%	68,4	61,9	64,0	75,9	74,3	63,33	73,5
Water, metric tons per hectare, in the top meter layer (aver. of 14 deter. in 3 years)	3355,6	2892,3	3201,8	3396,7	3534,4	3043,7	3252,5

Note: Comma represents decimal point.

divide and the lower north slope. Thus, for the three years, nitrate contents in the plow layer averaged 205.7 mg per 100 g soil on the lower south slope, and were much less (60.4-2.3 mg) on other areas. In the 40-60 cm layer the content on the divide averaged 44.4 mg, on the lower north slope 36.1 mg, and was less on other areas (15.0-29.1 mg per 100 g soil).

Obviously, in certain periods the intensity of nitrification in the lower soil horizons is inversely related to that in upper horizons. When nitrification is vigorous in the upper layers (lower south slope), it is limited in lower layers by insufficient oxygen. In soils on the ridge and lower north slope, where nitrate formation is weaker in the plow layer, anaerobic conditions are relatively better in lower horizons, if they have sufficient moisture and humus.

Further, the Table 2 it is apparent that the nitrate content of the soils changes with time. In the spring-summer period, with rising air temperature, normal moisture, and sufficient soil porosity, nitrate formation proceeds quite rapidly and the amount gradually increases. In most cases the nitrate content falls sharply at the end of the summer, which is explained by the predominance of disappearance over formation at this time. Drying soil, falling temperatures, and gradual compaction of lower layers as a result of cultivating only the surface during the summer, leads to a tapering off of nitrification. Under these conditions, the biological absorption of nitrates by soil microorganisms, partial leaching by rainfall, and possibly denitrification, causes considerable decrease in the content of nitrates in the soil. However, it must be mentioned that leaching apparently has limited significance in the summer because of insufficient soil moisture. Rains from May to July (167 mm in 1951 and 187 in 1952) moistened the soil no deeper than 10-30 cm.

The data of Table 2 show that nitrate changes follow different tendencies for different elements

of relief. While from May 15 to July 3, 1951, nitrate content of the plow layer increased on other plots, it fell sharply after July 7 on the middle south slope. A similar observation between south and north slopes was made in 1952. Our observations show (Table 3) that in this case nitrate changes are determined primarily by different hydrothermal soil conditions on different elements of relief.

As the data in Table 3 shows, up to July 3 the nitrate contents on all areas, except the middle of the slope, increased along with the increase in air temperature. However, on the middle slope, the nitrate content decreased more than four-fold between June 7 and July 3. Here the limiting factor in nitrification appeared to be insufficient moisture. Below 40% of saturation, soil moisture was apparently insufficient to support normal nitrification even at high temperatures. Nitrate determinations on August 9 showed that the concurrent decreases in temperature and moisture sharply limited nitrification on all plots. Nitrate contents decreased several fold, apparently on account of biological absorption, leaching, and possibly denitrification.

Finally, the data of Table 2 shows that nitrification in soils depends on the exposure of the slope. Nitrate contents of soils on the north slope were considerably lower than those of soils on the south slope. This difference was greatest in the spring, when, with ample moisture on both slopes, the deciding factor was temperature. The south slope, as is known, becomes warmer than the north slope and therefore nitrification proceeds earlier and more intensively in the spring. Later in the season, with relatively uniform temperatures and moisture, this difference gradually disappears. At the end of the growing season in 1951, the difference was reversed. This is explained by more adequate moisture on the north slope than on the south slope at this time.

Conditions for microbial processes, including nitrification, in soils are different on different elements of relief. In 1953, a single

Table 2

Changes in nitrates in the soil as affected by relief, mg NO₃ per kg of oven-dry soil

Deter- mination date	Depth, cm	Parts of the south slope			Ridge	Parts of the north slope		
		Lower	Middle	Upper		Lower	Middle	Upper
Data of 1951								
May 15	0—20	211,2	36,0	43,6	74,4	31,2	16,3	Not det'd.
	20—40	38,8	6,4	14,4	16,0	7,8	7,4	"
June 7	0—20	301,7	58,2	55,6	70,8	36,0	22,6	"
	20—40	59,6	19,8	42,4	69,2	21,2	8,4	"
July 3	0—20	566,0	12,6	179,4	306,4	51,6	46,8	"
	20—40	29,8	6,6	27,8	32,4	17,6	14,2	"
August 9	0—20	49,2	10,1	38,4	14,2	56,2	37,6	"
	20—40	9,6	4,4	28,0	13,0	38,2	11,6	"
Data of 1952								
April 27	0—20	95,4	76,4	Not det'd.	48,7	26,0	15,9	14,3
	20—40	110,3	71,6	"	89,7	34,3	11,2	12,5
May 23	0—20	487,8	120,5	97,2	173,6	80,9	46,0	61,7
	20—40	352,0	80,0	66,1	130,2	91,7	33,3	37,6
June 7	0—20	154,0	81,5	106,0	84,0	139,0	78,0	132,0
	20—40	226,0	59,0	97,0	222,0	162,0	78,0	69,0
July 15	0—20	286,0	149,0	128,0	111,6	201,7	98,3	101,7
	20—40	259,0	57,1	51,9	143,0	111,0	68,0	50,0
August 5	0—20	295,0	75,0	83,1	108,1	201,3	78,0	140,5
	20—40	140,7	33,0	35,1	77,2	101,5	48,3	34,4
Data of 1953								
April 22	0—20	27,7	20,5	29,3	20,7	26,7	29,4	21,3
	20—40	19,5	8,4	18,7	38,2	24,1	7,7	16,8
May 26	0—20	67,3	48,0	29,1	50,5	36,1	26,8	25,0
	20—40	52,1	16,6	33,2	39,0	37,3	18,2	21,5
July 1	0—20	160,0	49,6	71,4	42,7	97,8	59,4	53,0
	20—40	52,9	9,1	11,6	10,7	76,0	19,9	18,3
August 1	0—20	30,6	48,6	27,9	95,2	46,8	46,3	9,8
	20—40	24,7	19,1	7,4	83,0	52,8	28,2	11,6
Average of the three years								
	0—20	205,7	60,4	74,0	92,3	79,2	64,2	62,1
	20—40	105,7	30,8	36,1	65,1	59,6	27,3	30,1

Note: Comma represents decimal point.

determination was made of the number of microorganisms in the plow layer of soil on the lower and middle slopes, and on the ridge plot. The quantitative grouping of microorganisms was carried out according to the method of the Leningrad Institute of Soil Microbiology. The results are presented in Table 4.

From Table 4 it follows that the character of relief and erodibility of soils noticeably affects the conditions of microbial activity. Soil erosion deteriorates these conditions, and results in markedly lower numbers of microorganisms in the eroded soil. On the other hand, soil deposition favors their more intensive

growth. Therefore, more microorganisms were observed in soil on the lower slope than on the middle slope.

The nitrate content in the soil from different plots varied directly with the total number of soil microorganisms, as well as their ammonifying and nitrifying groups (Table 4). Thus, changes in nitrate content are not only an indication of nitrification, but are intimately connected with the general biochemical processes in soils at a given time.

The foregoing data show that plants experience widely varying nitrate nutrition as a result

NITRATE CHANGES

Table 3

Changes in nitrate in the plow layer as affected by changes in soil moisture and air temperature (data of 1951)

Element of relief	Determination	Determination date			
		May 15	June 7	July 3	Aug. 9
Lower part of slope	Average air temperature during the preceding 15 days, °C	10,7	12,0	19,7	15,2
	Relative soil moisture in % of saturation when nitrates were determined	60,0	66,0	45,0	37,0
	Nitrate content, mg per kg soil	211,2	301,7	566,0	49,2
Middle part of slope	Relative soil moisture, %	63,0	62,0	40,0	33,0
	Upper part of slope	36,0	58,2	12,6	10,0
Upper part of slope	Relative soil moisture, %	51,0	56,0	45,0	31,0
	Nitrate content, mg per kg soil	43,0	55,6	179,4	38,4
Ridge	Relative soil moisture, %	55,0	59,0	46,0	36,0
	Nitrate content, mg per kg soil	74,4	70,8	306,4	14,2

Note: Comma represents decimal point.

Table 4

Number of microorganisms in the plow layer on different elements of relief (May 26, 1953)

Element of relief	Millions of organisms per g soil			Nitrate content, mg per kg soil
	Total	Including		
		Ammonifiers	Nitrifiers	
South slope				
Lower part	182,3	22,5	0,0322	67,3
Middle part	161,4	18,4	0,0265	48,0
Ridge	174,3	20,18	0,0282	50,5
North slope				
Lower part	155,6	19,3	0,0246	36,1
Middle part	114,8	15,4	0,0221	26,8

Note: Comma represents decimal point.

of local relief and erodibility of soils. Starting from these premises, we carried out some experiments in 1951 and 1952 on the efficacy of different fertilizers on the experimental areas (on the south slope and ridge). The experiments were replicated three times with plots 5 x 10 meters in size, using the following fertilizer treatments: control, nitrogen, phosphorus, nitrogen plus phosphorus, nitrogen plus phosphorus plus potassium.

Ammonium nitrate, superphosphate, and potassium chloride were used at rates of 60 kg of active element per hectare. The preceding treatment of the experimental plots was buckwheat in 1951 and fallow in 1952. The fer-

tilizer was plowed under in the spring, and spring wheat was seeded with a horse seeder at the rate of 160 kg per hectare.

The average yield data for both years are shown in Table 5.

The data (Table 5) show that phosphorus gave the greatest yield increases on the soil deposited on the lower slope and on the non-eroded ridge soil. Nitrogen fertilization showed more effect on the eroded soil on the middle slope. Potassium fertilizer, added to the mixture, gave the least additional yield on all plots. Obviously, the deposited soil, in which nitrification proceeded more intensively

Table 5

Yield of spring wheat as affected by fertilizer treatment on different elements of relief, centners per hectare

Treatment	Part of slope				Ridge	
	Lower		Upper			
	Yield	Increase	Yield	Increase	Yield	Increase
Control	18,8	—	13,89	—	16,05	—
N	19,85	1,05	16,60	2,71	17,70	1,65
P	21,35	2,55	15,00	1,11	18,23	2,18
N+P	21,80	3,0	17,05	3,16	19,10	3,05
N+P+K	22,30	3,50	17,70	3,81	19,0	3,85

Note: Comma represents decimal point.

furnished more nitrogen to plants. Therefore, the addition of phosphorus to this soil gave a greater yield increase than did nitrogen. An analogous situation was observed on the ridge, where the soil was less well supplied with phosphorus, but nitrification proceeded adequately.

The eroded soil on the middle slope, lowest in nitrate, required primarily nitrogen fertilizers, and gave larger yield increases with them than with phosphorus.

Conclusions

1. Soil erosion, removing soil from one spot and depositing it in another, causes variations in soils on different elements of relief.

Eroded soils, contrasted with normal, are characterized by lower thickness of humus horizon, humus content, moisture, poorer structure, etc. The opposite picture is observed in deposited soil.

2. As a result of diverse soil conditions, nitrification proceeds differently on different elements of relief. As a rule, the largest nitrate content in the spring and summer under fallow is observed in soil deposited on the lower slopes, somewhat less in non-eroded soil on the ridge, and the least in eroded soil on

the middle slopes.

3. The exposure of the slope also greatly influences nitrification. Soils on south slopes are considerably richer in nitrates than those on north slopes. This difference is greater in the early spring.

4. Our preliminary experiments with spring wheat on eroded soils showed that nitrogen fertilizer gave the largest yield increases. On non-eroded or deposited soils, phosphorus gave the best response.

5. The experimental data confirms that fertilization of soil in areas of broken relief must be differentiated in each case according to the erodibility of the soil.

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DISCUSSION

THE PROCESS OF SOIL FORMATION

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One of the unresolved and disputed questions in contemporary soil science is that of the nature of the soil-forming process, the basis of genetic soil science. Until quite recently the process of soil formation was treated from two opposed points of view.

According to the first viewpoint, known as the eluvial theory, the whole diversity of phenomena in soil formation could be reduced to the changes undergone by various compounds and their movement in the upper stratum of the weathering crust.

According to the second viewpoint (1, 6, 18), the essence of soil formation is to be found in the synthesis and decomposition or organic matter. Thus in Vilenskiy's view (5), the ash elements of plant nutrition become dissolved when the litter decomposes, but are taken up by the plants and not carried away. The accumulation of the ash elements of plant nutrients as organic matter, and plant residues and humus is "the main distinguishing feature of the soil as a natural body and the essence of the process of soil formation." This "theory" of the total uptake of these substances is clearly in conflict with Vil'yams' hypothesis that the exchange capacity of plants is selective. Vegetation cannot take up all the elements that are released by weathering nor in the same quantities. Many elements that are partly but not absolutely organogens can be involved in the major geological cycle outside the vegetative period, and in so doing refute the theory of the total uptake of elements.

Rode (12, 13, 14) has recently treated the process of soil formation as "a totality of interrelated phenomena (i.e., elementary processes) of the conversion and transfer of matter and energy, taking place in the soil layer." He grouped elementary processes into five main pairs of opposing phenomena and processes.

1. The synthesis of organic compounds, including humification $\rightleftharpoons$. The decomposition of organic compounds.

2. The synthesis of mineral compounds, including the biological synthesis of secondary soil minerals $\rightleftharpoons$. The decomposition of mineral compounds, including secondary minerals.

3. Biological accumulation of organic and

mineral compounds $\rightleftharpoons$. The leaching of organic and mineral compounds.

4. Water intake into the soil, principally from the atmosphere $\rightleftharpoons$. Loss of moisture from the soil by transpiration, evaporation and various types of runoff.

5. The arrival of radiant energy at the surface of the soil and heating of the soil $\rightleftharpoons$. Radiation of soil energy into the atmosphere and into cosmic space and cooling of the soil."

Rozov (15) took these opposing phenomena as a basis for elaborating the principles of genetic soil classification. Blagovidov (4) comments that Rode's treatment of the genesis and development of soils is "profound and on the whole correct." We shall see that Rode's views provide a theoretical basis for the solution of extremely important questions, including the elaboration of a genetic soil classification. The questions indicated previously and clarification of the genesis and evolution of soils are dependent on one's approach to the essence of the process of soil formation, and solution of these problems enables one to plan the principles of melioration and soil cultivation.

Returning to Rode's views, one should note that such processes as the synthesis and decomposition of organic matter and minerals, and biological accumulation and the eluvial process cannot be classified as elementary processes. The leaching of the decomposition products of organic matter is a slow and complex process. Firstly, not all organic matter passes into solution under the influence of atmospheric precipitation and not all the dissolved mass of organic matter penetrates through soil. Secondly, there is selective uptake of a large quantity of elements by soil microorganisms and plants. These elements are thus removed from the downward moisture flow and take part in the synthesis of organic matter. The accumulation of organic matter is unthinkable without uptake and subsequent synthesis, leaching of organic matter precedes the process of its decomposition, and all these interrelated phenomena are also separate elements in the cycles that are typical of the minor biological cycle.

When commenting on the opposing nature of the processes, Rode indicated the direction of the processes and the connections between them

by arrows, e.g., the transition of the biological accumulation of organic and mineral substances to the leaching of the latter, which is fully possible. One is automatically at an impasse however if one considers this second arrow which points the opposite way, namely, to the conversion of leaching into the accumulation of organic and mineral compounds.

There is a case in nature in which a downward moisture flow is replaced by upward flow and deposition of salts takes place at the surface of the soil; a solonchak soil is formed, but the deposition and accumulation of organic compounds in this manner has not as yet been proved. We will assume that Rode (like other natural scientists) considers that biological accumulation precedes the uptake and synthesis of the separate elements, but in this case it is impossible to accept the view that synthesis and decomposition, accumulation and removal govern the formation of soils. One assumes from the arrows that these are opposing processes that proceed with equal force and rate, and that although motion is indicated this is only a temporary deviation to one side or the other that points to an invariable state of equilibrium. In this case Rode has made use of opposing phenomena and processes that actually exist to justify his old hypothesis of a soil climax.¹ Rode and others note the existence of opposed processes in soil formation and at the same time take into consideration the existing interconnection and interdependence of the soil-forming process.

Although the opposed phenomena and processes noted by Rode take place in the soil, they do not reveal the nature of its formation. The synthesis and decomposition of organic matter is typical of all organisms, and these processes can and do take place outside the soil. The synthesis and decay of minerals is simply weathering, which may in some cases be unrelated to soil formation. The intake and output of heat and moisture by the soil is also not specific to the soil, since it occurs in other bodies. Both Rode and other investigators failed to notice and underestimate the features that are peculiar to the process of soil formation.

In a paper by Yurova (17) we find the statement that "life is the cause of the process of soil formation and its determining factor, while the chemical processes that occur in the soil are a result of the vital activity of the organisms that inhabit it." Life can be found in any lake, river, sea or ocean and even in the atmosphere, but these media are certainly not related to soil formation. In this connection it should be remembered that "unless one studies what is peculiar to contradictions it is impossible to say what precisely distinguishes one phenomenon from another or to reveal the

specific causes or specific foundations for the motion and development of phenomena, and it is impossible to distinguish between phenomena or to define the range of scientific investigation."²

Dokuchayev, the founder of genetic soil science, established that "soils always have their own specific origin, they are always and everywhere the result of the combined activity of the parent material, living and dead organisms (both animals and plants), climate, the age of the country and the local relief." Briefly, but with absolute clarity, Dokuchayev formulated a number of statements that reveal the true nature of the formation of the soil as a separate entity in natural history, that develops under the influence of five "equivalent" factors. In later works the totality and equivalence of the soil-forming factors was treated and developed in different ways. It was thought for a long time that climate was the governing factor in soil formation. This hypothesis found its expression in the eluvial "theory."

Of late years there have been more and more references in the literature to stressing the significance of the biological factor in soil formation. In an attempt to develop this hypothesis in working out a soil classification, Rozov (15) and Ivanova (10) distinguish the following soil subtypes: 1) biogenic; 2) biolithogenic; 3) bihydrogenic; and 4) biohalogenic. The names show that these authors have added the prefix "bio" to the subtypes: halogenic, hydrogenic and lithogenic, borrowed from Vilenskiy's soil classification published in 1924.

We are inclined to think that this is a purely mechanistic approach to the treatment of the biological factor when making a soil classification.

These mistakes are a result of giving pride of place to one or other of the factors. Thus, for example, Ponomareva (11) comments, when assessing the various factors, that "only the vital activity of organisms is directly related to the degree of development of the soil, Dokuchayev's individual factors—climate, parent material, relief—are most favorable to soil formation at an optimum level of its properties or combinations and are unfavorable and even disastrous at a maximum or minimum." We are in agreement with the criticism of Ponomareva's hypotheses in the article by Belova (2) and only wish to examine one conclusion which Ponomareva formulates as follows:

"The soil is the result of the life and death of generations of organisms, from whom life is constantly reborn. This is a great example of 'negation in nature'." We shall attempt to clarify the role of this law in soil formation. To this end we cite Engels' statement that negation of the negation is "the reproduction of the old at a higher level."³ Engels illustrates this

¹ Editorial note. The criticism of Rode's views is based on an incorrect interpretation of the text of his book. By his arrows Rode only indicates the direction of the elementary processes and not their "strength and rate." Therefore the author's conclusion that Rode justifies a soil "climax" from his views is unfounded.

² Mao Tse Tung. On contradictions. Collected works, Vol. 2, p. 424. Inostranizdat, 1953.

³ F. Engels. Anti-Dühring, p. 327. Gospolitizdat, 1953.

hypothesis by a number of examples, but we need only to refer to one, in which he states that "First the original earth-crust brought into existence by the cooling of the liquid mass was broken up by oceanic, meteorological and atmospheric-chemical action, and these disintegrated masses were deposited on the ocean floor. Local uplifts of the ocean floor above the surface of the sea subject portions of these first strata once more to the action of rain, the changing temperature of the seasons and the oxygen and carbonic acid of the atmosphere. These same influences acted on the molten masses of rock which issued from the interior of the earth, broke through the strata and subsequently solidified. In this way, in the course of millions of centuries, ever new strata are formed and in turn are for the most part destroyed, ever anew serving as material for the formation of new strata. But the result of this process has been a very positive one: the creation, out of the most varied chemical elements, of a mixed and mechanically pulverized soil which makes possible the most abundant and diverse vegetation."⁴ As we see, the conversion of the parent material into soil takes place through the prolonged changes of the properties of the initial parent material and its acquisition of new features that predetermine the possibility for vegetation to become established and finally to convert the parent material into soil, i.e., to a new natural body. It should also be noted that one often finds that the nature of the soil-forming process is identified with its mechanism. Thus, for example, Gerasimov and Glazovskaya (7) are of the opinion that "the process of soil formation is a combination of diverse chemical, physical and biological phenomena that are continually taking place in soils and that determine the composition and properties of the soil mass." The whole diversity and complexity of the phenomena of soil formation are often reduced to purely physicochemical phenomena, and in particular to the adsorption of sodium ion or another cation by the colloid complex.

When certain views on the formation of soils are analyzed from the standpoint of dialectical materialism, one can conclude that the development of soils is a complex process that is influenced by not one but many contradictions. When analyzing any process that is complex and contains more than two contradictions one must look for the principle contradiction (3).

The conversion of the parent material into soil starts at the moment that vegetation settles on it. The history of the unity of opposites or the contradiction between the minor biological and major geological cycles also begins from this moment. This is the principle contradiction and it also reveals the specific feature that distinguishes the soil-forming process from other natural processes. Before proceeding to analyze the principle contradiction and its influence on the other contradictions, we must deal briefly with the nature of the minor and major cycles. According to Vil'yams, the major geological cycle arises from the interdependence of the geological parent material and atmospheric

precipitation, which, on penetrating the parent material, dissolves a number of substances "and carries everything in solution to the ocean by the rivers."

The major role in the contradictory relations between the parent material and atmospheric precipitation belongs to precipitation that causes vertical, percolation and surface runoff. The rate of the vertical (first) branch in the major geological cycle and the depth to which it penetrates are dependent both on the amount and type of precipitation and on the structure and texture of the geological parent materials. The main work performed by moisture when it penetrates a layer of parent material is the mechanical transfer of solids, the dimensions of which may vary considerably, along fissures and voids. In its advance, atmospheric moisture also dissolves a number of salts which are carried downward into the soil material layer where, if the flow does not reach the ground waters, they pass out of solution and accumulate on crystallization to form illuvial horizons rich in carbonates and gypsum.

Surface runoff, whether or not it reaches large accumulations of water, should be treated as the second branch of the major geological cycle. If surface runoff does not reach rivers and seas but flows into a closed basin it will help to redistribute various compounds, including nutrient elements, within the continental land mass. The rate and pattern of surface runoff is governed by local relief.

Since percolation differs from surface runoff in both rate and salt composition it should be treated as a new, third branch of the major geological cycle that arises as a result of the soil-forming process. Unlike ground waters, percolation is not associated with the base erosion and its movement is governed by variation in the relief of the permeable horizon within the soils. The characteristic feature of each of these branches of the major geological cycle is that the atmospheric precipitation that enters the parent material or soil reacts with the solid phase and that dissolved substances are carried with the percolation to lower lying horizons of the parent material or removed from the surface to different waterways.

Taken as a whole the three branches (vertical wetting of the soil down to the ground waters or to a depth below which the root systems of plants penetrate, percolation [top water] and surface runoff) make up the major geological cycle. This unity should not, however, be treated as the harmonious coexistence of all the branches simultaneously in every soil; on the contrary, their development is antagonistic. The nature of the contradiction is that one branch is converted into another with the passage of time. Thus, for example, at certain stages in the development of the soil-forming process, downward flow will be transformed into its opposite of upward flow ("the solonchak stage") or into internal and surface runoff. We shall consider below why one type of flow is transformed into another, after we have examined the nature of the minor biological cycle.

In the principal stages in the development of the soil-forming process the minor biological

⁴F. Engels. *Anti-Dühring*, p. 327. Gospolitizdat, 1953.

cycle is one of the dominant aspects of the principle contradiction and provides the key to one of the basic principles first noted by Vil'yams, namely that "the only way to impart to an element a finite, quantitatively delineated quality of the infinite is to give it cyclic motion, to compel it to enter into the cycle (6, p. 57). In clarifying the content of this principle and simultaneously explaining the historically conditioned interconnection between the major and minor cycles, Vil'yams notes that these relationships "underlie the symbiotic relationships between categories of organism," which as a result of prolonged adaptation have acquired the capacity to extract "a series of elements which, when constantly drawn into a new biological cycle that is small by comparison with the major biological cycle, will be removed from the path of the major cycle for a prolonged period, if not forever, and will circulate in an ever widening spiral in the opposite direction in the minor biological cycle" (6, p. 57).

This hypothesis postulates an extension in the circulation of nutrients rather than their conservation in organic matter. This extension in circulation does not take place in a closed circle but along a spiral, and this assumes not repetition but the development of the processes on a new basis. Both the contemporary conditions of mineral nutrition and those under which it was formed in the process of its historical development are reflected in the plant, as in other organisms. The uptake by plants of all the elements of mineral and other types of nutrition is not a passive process, each plant exhibits a selective capacity. In accordance with its features, each plant is selective in relation to its external environment, extracting from it what it requires at each stage of development.

One would therefore assume that the environment helps to alter the organism and that the organism, in its turn, exerts a corresponding influence on the environment. The effect of the organism on the environment is dependent both on the features of individual plants and on those of whole groups, the development of which usually conforms to the different demands that separate species make on the environment. When the environment does not supply the inner needs of the plants, when, for example, some element is not present in the required amount, the plant is compelled to forsake the given habitat or to alter the reaction of the environment by root secretions and thus to ensure that the plant takes up compounds containing the required nutrients in solution from the parent material. This latter phenomenon, i.e., the action of vegetation on the parent material (weathering) is most widespread in nature. In the course of time ever larger amounts of mineral nutrients are drawn into the minor biological cycle, which, as we see, is extended by the active influence of the vegetation on the mineral substrate. The increase in the mineral nutrients intensifies biological processes that accumulate nitrogen and other nutrients, i.e., the fertility of the soil is gradually increased.

The minor biological cycle can be subdivided by the rate of circulation of different substances and also by certain biological features of different plant formations into three independent but interrelated cycles, which in their turn are divided into a number of links. The first, known

as the "minor cycle," is effected by a plant formation consisting of algae, fungi, actinomycetes and bacteria. The representatives of this flora are responsible for the fixing of atmospheric nitrogen into complex compounds, nitrification, denitrification, and the formation of various acids and other organic compounds. Each link in the minor cycle differs in the nature of the substances that enter the external environment as a result of the vital activity of individual groups or whole communities of lower organisms or of the decomposition of the dead material. Lower organisms only live for a few days or even hours; when they die the organic mass is mineralized quite rapidly and the simple salts and other compounds containing nutrients thus liberated are re-used by lower or higher plants. The rapid circulation of nutrients in this cycle is its typical feature and justifies the term "minor cycle"; it also shows that the minor biological cycle has a very broad basis for development. No large accumulation of nutrients is found, since the layer of the parent material or soil in which lower organisms are concentrated is no more than a few millimeters or, at best, centimeters thick. A part of the nutrients set free when organic matter is mineralized therefore enters the major geological cycle or is assimilated by plant roots, i.e., are incorporated in the "medium-plant" cycle, which can be divided into two links. The first incorporates the whole diversity of processes associated with the synthesis of organic matter, while the second is typified by the decomposition and mineralization of plant litter. This cycle affects a layer several meters thick and the various substances circulate less rapidly in it owing to the longer retention of substances in the growing part of the plant and in dead organic matter, from which the salts of alkaline cations are completely released; those of the alkali earth cations are partly released in the first year, while iron and aluminum remain almost entirely bonded with the organic part of the litter. The amount of organic matter is reduced in semi-decomposed litter and in steppe-mat and there is a simultaneous relative increase in the ash content.

The rate of mineralization of plant litter depends on external conditions (moisture and temperature) and also on the lower organisms inhabiting the litter or mat. The mineralization of the organic matter is a very complex and many sided process and the various substances that are liberated take part repeatedly in the biological cycle. When the plant material is eaten by animals or used by man, the various substances are involved in the "major cycle" of minor biological circulation.

The liberation of nutrients and other substances in the various links of the major cycle is an uneven process and does not usually occur at the point at which they were taken into the cycle. When organic matter in the form of a dead material is mineralized, a large amount of various compounds is liberated, some of which re-enter various biological cycles. The remainder reacts with the components of the major geological cycle. As atmospheric precipitation percolates through litter it is enriched with dissolved substances such as organic acids, organo-mineral compounds and simple salts. All these substances are involved in a diversity of complex

reactions with the parent material when they reach it with percolation. Acids that dissolve a number of mineral substances form different salts, organo-mineral compounds and complex aggregates; simple salts enter into base exchange when they react with the colloidal particles of the parent material. As the percolate passes through the parent material the concentration of the solution changes, initially by the loss of ferric and aluminum hydroxides and subsequently of calcium and magnesium carbonate; if the percolate does not reach the ground waters, a horizon with a maximum accumulation of sesquioxides, carbonates, sulfates and chlorides is formed in the soil material layer.

All these phenomena are evidence of the existence in the parent material during soil formation of mechanical movements, physical, physicochemical, biochemical and chemical processes that comprise the mechanism of the soil-forming process. The various genetic horizons of the soil profile are formed by this mechanism. The formation at a slight depth of an illuvial horizon, rich in clay particles, which occurs in the formation of podzols, solods and solonetz soils, eliminates the vertical penetration of water and leads to the development of percolate or (as often happens) surface runoff. When higher plants on solonetz soils in which there is a large amount of easily soluble salts in the root layer do not receive sufficient moisture they thin out and in places disappear entirely. The bare patches are then occupied by a vast quantity of lower plants, the biological features of which make them incapable of fixing the surface of the soil and preventing the development of erosion processes. This is a clear example of the way in which the biological cycle ceases to exist with the passage of time. The soil-forming process, i.e., the contradictory interrelationships of the major and minor cycles, lead to the complete suppression of the minor biological cycle and development of one branch of the geological cycle that destroys and erodes the soil instead of creating it. This can happen on plains as well as on areas with a highly dissected hydrographic net.

When salts are raised with upward flow of water and subsequently accumulated in the root layer, the minor biological cycle is suppressed and the soil, or more accurately solonchak, enters on the geological stage of its development. The same thing occurs in the development of the water-logging process, which is due to external or internal conditions, i.e., to the formation of the same impervious illuvial horizon. The main cause for the conversion of the soil-forming process into its opposite is disruption of the dynamic equilibrium in the interrelationship between the minor and major cycles. In this case dynamic equilibrium should be treated as a manifestation of objects in a state of quantitative change, while the breakdown of the whole and the disruption of dynamic equilibrium is a manifestation of objects in a state of qualitative change, that indicates the transition of one process into another.

Unequal development of the sides of the principal and secondary contradictions is the main cause of quantitative changes that lead to the replacement of one process by another. If

all other conditions are equal, the uneven development of the process of soil formation with the passage of time can be affected by lack of uniformity in the texture and composition of the parent materials, the level of salinity of the parent material, diversity of vegetation, extent of plant cover, different surface forms and uneven surface wetting, etc. If the thickness of an identical parent material varies in flat areas, this may often cause a number of variations in soil formation. In some cases a slight difference in the level of salts in the parent material at the level of the minor biological cycle changes the nature of development in the soil-forming process.

It has long been known that the soil-forming process develops unevenly on parent materials of identical origin in which the calcium carbonate content varies, and that this unevenness accounts for the spatial formation of intricate soil complexes. The noticeable difference in the soil that is often observed on the same parent materials with identical chemical and physical properties and uniform plain relief is due to marked differences in the composition of the plant groups. Every unevenness, including uneven density of plants, helps to differentiate the quantitative changes that lead, with the passage of time, to an observable unevenness in the formation of the soils.

We can now proceed to an evaluation of the individual factors.

Although he noted the continual, regular genetic connection between the separate factors, Dokuchayev (8) did not reveal the essence of this connection. This difficult problem was resolved by Vil'yams theory of the major geological and minor biological cycles (6), in which he showed, among other things, that the existing connection between climate and parent material is the real essence of the major geological cycle. The minor biological cycle is influenced by a third factor—vegetation. Two further factors—the relief and age of the country—cannot be equated or compared with the first three, since they are the forms in which the process of soil formation takes place. This hypothesis should not be seen as underestimating the importance of relief: on the contrary, if we bear in mind the contradiction between relief and the soil-forming process as a whole we can reveal then the interconnections that arise in natural landscape formation.

We have noted previously the influence of relief, as surface form, on the soil. In its turn, local relief is influenced by the soil-forming process in semi-desert conditions, for example, to form a definite type of landscape and this shows clearly that relief cannot be treated as a simple element in soil formation, since, as an element of the landscape, it enters into definite relationships with other landscape elements including the soil.

Like relief, the age of a country, or the time factor, is one of the forms in which any process, including that of soil formation, takes place. Therefore, since time is largely a measure, it enables one to compare and contrast, e.g., the rate of progression of a given stage or separate process in soil formation.

Each stage of any process is marked by a period of time in which only quantitative changes, leading to the formation of new phenomena within the mechanism of the process, occur. The change in the mechanism of the process subsequently leads to the replacement of one stage by another and often creates the conditions for the development of a new process or even two processes. This is why a soil can have a double or even a triple name, e.g., sod-podzolic or sod-podzolic-gley, meadow solonetz-solonchak, etc. Nobody questions a terminology in soil classification such as moderate and strong solonetz, moderate and highly waterlogged, which points to the degree of development reached by the developing process. There are also such terms as residual-podzolized or sod-residual-solodized, which record the level of regression of a given process.

The terminology that has developed historically usually reflects the principal contradiction, but owing to lack of knowledge the order of importance of the contradictions has often been reversed in the application of these terms.

A new feature represented by slight changes is often underestimated although, as Mao Tse Tung points out, its development may lead in course of time to complete disappearance of the old: "the old phenomenon is transformed into a new phenomenon with its own specifically new feature."⁵ Thus, for example, the setting of sod process on podzolization leads inescapably to the domination of the former and the formation of new typical soil groups. When, however, one type of vegetation is replaced by another (in the cutting of timber or in plowing) the mechanism of soil formation is retained for a long time and this helps to restore the old process. The development of the latter is also stimulated by regional conditions, of which the input of solar energy and its accumulation is the principal contradiction providing the basic impetus for the formation of the natural complex typical for the given zone.

If one knows the factors that describe the different sides of the principal contradiction one can make a differential approach to the elaboration of agricultural practices to stimulate the development of a side that is positive from the point of view of agricultural production and to restrict development of the other side. For soils such as solonetz and solonchaks, in which both sides of the principal contradiction are unfavorable to agricultural production, it is necessary to fundamentally alter their nature, and the principal contradiction enters on the plane of man's struggle with nature.

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⁵ Mao Tse Tung. On contradictions. *Collected works*, Vol. 2, p. 445. *Inostranizdat*, 1953.

METHODS

THE RATE OF SOIL FORMATION IN OLD QUARRIES OF CALCAREOUS ROCKS AND SECONDARY CHANGES IN BURIED LIGHT-GREY FOREST SOILS¹

M. P. SMIRNOV

Two storey-soils have been found in the Kashira rayon of the Moscow Region (Maleyevo village, "Nineteenth Party Congress" Collective Farm). The upper layer consists of humus-calcareous soils on old limestone quarries and the lower of buried light-grey forest soils on fine clay loam deposit. In this paper we have used the term "anthropogenic humus carbonate soils on buried light-grey forest soils" to describe these two storey soils.

The region described is the northern part of the Central Russian elevation made up of rocks from the Moscow section of the carboniferous system, which emerge on the surface only in the river valleys. On the slopes and in the watersheds the parent rocks are bedded under two-layer clay loams. The soil-forming parent material is usually fine clay loam deposit.

Anthropogenic humus carbonate soils have formed in the old calcareous rock quarries. Since in some places it did not prove possible to establish when the limestone was worked, it was suggested that the different soils might be compared on the basis of morphological descriptions and analytical data and that this might yield differences in regard to the rate of humus carbonate soil formation in the old calcareous rock quarries and also on the degree of transformation of the buried light-grey forest soils.

For this purpose it was necessary first to compare anthropogenic humus carbonate soils of different ages and secondly to compare these with natural humus carbonate soils on leached limestone. In the same way it is possible to compare light-grey forest soils buried at various times in the past with one another and with light-grey forest soils bedded under natural conditions.

Anthropogenic humus carbonate soils develop on the lower parts of slopes among the light-grey and grey forest soils. We found such soils on a right-hand (downstream) slope running down to the Medvedka River and to slopes running down to the Vdovitsa. To show the morphological character of anthropogenic humus carbonate

soils 80-100 years-old we shall describe their profile.

Profile 111. Slope down to Medvedka valley. Gradient 12° to WNW. Microrelief — crests, small ridges, soddy hillocks, but on the whole level surface. Vegetation includes a variety of grasses and herbs (*Poa angustifolia*, *Alopecurus pratensis*, *Trifolium repens*, *Cichorium intybus*). Small quantities of juniper (*Juniperus communis*). Pasture is of poor quality. In places the soil effervesces poorly at the surface but violently at a depth of 14-47 cm. The top part of the A₁ layer of the buried soil effervesces poorly.

Asod 0-8 cm. Grey, dry fine clay loam, granular, very strongly penetrated by roots, small amounts of small limestone fragments. Effervesces at the surface. Marked transition as roots diminish and compacting increases.

A₁ 8-20 cm. Grey, dry, fine clay loam, with very pronounced small blocky-granular structure, compacted, contains many roots, and also more or less large fragments of limestone and lime meal. Effervesces violently, particularly in the lower part; many passages caused by worms, insects and ants. Very pronounced transition, color changes and the amount of limestone and weathering products thereof increases.

AB 20-31 cm. A light-grey horizon, darker in places, dry, fine clay loam, compacted in places and loose in others, medium, blocky, granular; roots are found in appreciable quantity; many more limestone fragments than in the previous horizon (up to 25%-35% of the total volume of the horizon). Many passages made by animals. Effervesces violently. Transition uneven but fairly abrupt — color changes and the amount of limestone increases.

C 31-50 cm. Whitish, light-grey in places, dry, fine clay loam, granular-small blocky, structureless in places, fairly loose with an abundance of limestone rubble, flakes up to 25 cm long and limestone debris (limestone up to 90% of the total volume of the horizon). A good many roots. Effervesces very violently; abrupt transition with change of color and diminishing amount of limestone.

Buried Soil

A₁ 50-60 cm. Light-grey, moist, fine clay loam, silty-unstable blocky, loose to the point

¹ This paper is based on material collected in the course of the author's work in the soil erosion division of the Dokuchayev Soil Institute in 1957 and 1958.

of friability (the horizon was plowed in the past), calcareous material is found in the upper part and effervesces but does not effervesce in the lower part and contains whitish powdering. Many passages made by animals and roots. Marked transition (color and compaction).

A₁ 66-72 cm. Dark brownish with grey tint, moist, fine clay loam, compacted, loose in places, silty small blocky, contains rootlets; does not effervesce, pronounced whitish powdering. Transition fairly abrupt (by the color and compaction).

A₂B 72-81 cm. Whitish with brown and darkish tongues and patches, fairly wet, medium blocky, platy, in places where there is much siliceous powdering, fairly compacted. Transition gradual.

B₁ 81-86 cm. Darkish brown with whitish coating, wet, coarse nutty (units 3-5 cm in diameter), compact, many passages by animals and rootlets, much siliceous powdering on the faces of structural units. Transition gradual.

B₂ 86-95 cm. Muddy brown, wet, with darkish coating in the form of film on the faces of structural units, coarsely nutty (6-7 cm), compacted, fine clay loam, much siliceous powdering in the form of tongues and on the faces of structural units. Transition gradual.

B₃ 95-120 cm. Brown with darkish coating on the faces of structural units, wet, fine clay loam, coarsely nutty-blocky, compacted, siliceous powdering on the faces of structural units. Transition gradual.

C 120-150 cm. Brown, grey, coarse clay loam, nearer to fine clay loam, coarse blocks with sharp edges, very compacted.

As can be seen from the foregoing description, the BC horizon, which was the parent material for the anthropogenic humus carbonate soil has already been altered by the soil-forming processes. This horizon has acquired specific soil properties (humus, plant roots, passages made by animals).

For the sake of comparison we give below the character of the profile of a younger anthropogenic humus carbonate soil 25-years-old. We found such a soil profile in the lower part of the right-hand slope to the Vdovitsa River, 300 m north of Maleyevo.

Profile 154. Slope to the Vdovitsa valley. Gradient 13°-15° to the west. Microrelief—hillocks, small knolls, on the whole level surface. Vegetation includes *Alopecurus pratensis*, *Poa angustifolia*, *Trifolium repens* and others.

A_{sod} 0-8 cm. Grey cinnamon-brown, dry, fine clay loam, granular, loose, very strongly bound with roots, contains limestone fragments. Effervesces violently at surface. Marked transition.

BC 8-25(30) cm. Whitish with greyish patches and streaks of humus, dry, medium clay loam, structureless, loose in places, compacted in others; limestone fragments (diameter

up to 10-15 cm) making up about 95% of the total volume of the horizon. Effervesces violently, many roots. Transition to next horizon abrupt and uneven.

Buried Soil

A₁ 25(30)-46 cm. Light grey, dry, medium clay loam, granular—small blocky, loose. Limestone fragments in the upper part; effervesces to a depth of 30-35 cm. Some rootlets. Transition fairly abrupt in regard to color.

A₂ 46-57 cm. White with brownish streaks, dry, medium clay loam, fairly pronounced, small blocky—mealy with elements of platiness, loose, does not effervesce, transition gradual.

B₁ 57-72 cm. Brown with pronounced whitish tint, moist, fine clay loam, medium nutty, compacted, contains some rootlets. Transition gradual.

B₂ 72-91 cm. Brown with spots of whitish powdering, wet, fine clay loam, coarsely nutty (units 5 cm in diameter), dark coating on faces of structural units, compact. Transition gradual.

B₃ 91-115 cm. Brown with dark coatings on faces of structural units, wet, fine clay loam, coarse nutty to prismatic structure; diameter of units 6 cm, compact, siliceous powdering in form of pockets. Transit gradual.

C 115-135 cm. Brownish dark blue, sticky, wet, fine clay loam, compact.

It can be seen from the foregoing description that the BC (8-25(30) cm) horizon, which is the soil-forming parent material of the 25-year-old anthropogenic humus carbonate soil, has changed less as a result of the soil-forming processes than the 100-year-old soil. The younger soil has only one sod horizon, with a much shorter profile than the older one. It can be assumed that the soils described are being eroded, since they are situated on slopes with a gradient of rather more than 10°. As they are well-drained, are not plowed and are protected from erosion by the sod development, the extent of erosion cannot be very great. Moreover, the more developed 100-year-old soil, in which, as we have seen previously, the sod process is less developed but which lies on a surface of almost the same gradient and on slopes equally exposed, could have undergone a greater amount of erosion. We may, therefore, conclude that in the development of the soil profiles there is a heritage of different maturity as a result of their different ages.

Before passing on to an examination of the analytical data for the soils investigated we must first describe the profile of natural humus carbonate soils on leached and weathered limestone near the old quarries. Such soils were found on the right-hand slope down to the Medvedka River not far from the contour of the 100-year-old anthropogenic humus carbonate soil described profile.

Profile 181. Right-hand slope to Medvedka River. Gradient 15° to the west. Small knolls

Table 1
Particle size analysis of soils, based on carbonate-free weight (N. A. Kachinskiy method)

Profile No.	Soil	Horizon	Depth, cm	Losses on HCl treatment, %	Particle content in % of dry weight of soil, diameters in mm							Hygroscopic moisture, %		
					>3	3-1	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001		<0.001	<0.01
111	Anthropogenic humus carbonate (young, 100-year-old) on buried light-grey forest soil	Asod	0-8	1.99	None	0.18	0.40	7.74	46.06	11.15	12.00	22.65	45.80	3.27
		BC	35-40	55.78	25.12	15.09	0.36	36.05	21.12	6.15	4.52	31.80	42.47	1.37
		A ₁ fossil	55-60	1.27	None	0.37	0.08	4.97	54.15	13.20	14.30	13.30	40.80	2.29
		A ₁ fossil	125-130	2.04	None	1.28	0.34	13.30	33.35	6.32	12.46	34.23	53.01	4.46
154	Anthropogenic humus carbonate (immature, 25-year-old) on buried light-grey forest soil	Asod	0-6	29.69	None	3.51	1.43	18.71	34.41	8.37	14.25	22.83	45.45	5.22
		A ₁ fossil	35-40	1.27	None	0.18	0.29	23.82	40.43	10.07	11.75	13.64	35.46	1.92
		A ₁ fossil	125-130	1.22	None	0.38	0.00	7.69	52.75	4.98	6.71	27.87	39.56	3.62
181	Humus carbonate (mature) on leached limestone	Asod	0-8	3.05	None	1.00	0.73	9.11	46.33	9.12	12.20	22.51	43.83	3.86
		B	45-50	2.22	4.10	3.54	1.48	13.30	35.93	8.06	11.36	29.87	49.29	3.74
		C	100-105	69.23	22.66	15.77	0.26	51.39	4.22	4.97	16.96	22.20	44.13	1.36
184	Light-grey forest on fine clay loam deposit	Asod	0-4	1.57	None	0.36	0.96	13.20	48.87	11.43	12.08	13.46	26.97	1.92
		B ₁	25-30	1.30	None	1.44	0.41	10.54	43.82	11.32	8.76	25.15	45.23	3.01

Note: Comma represents decimal point.

and hillocks on surface. Vegetation includes sparse shrubs of juniper (*Juniperus communis*), *Festuca pratensis*, *Poa angustifolia*, *Alopecurus pratensis*, *Trifolium repens*, *Cichorium intybus* and others. Low quality pasture. Signs of podzolization.

A_{sod} 0-8 cm. Cinnamon-brownish grey, moist fine clay loam, pronounced granularity; strongly penetrated by roots, comparatively loose. Transition gradual.

A₁' 8-30 cm. Grey with dark tint, wetter than the preceding horizon, fine clay loam, small blocky-granular, loose, some very fine limestone particles. Effervesces violently. The lower boundary is uneven and fairly sharp.

A₁" 30-40 cm. Lighter color than the preceding horizon, moist, fine clay loam, small blocky with elements of granularity, compacted. Includes small quantities of calcareous rubble and some rootlets. Effervesces violently. Transition gradual.

B 42-56 cm (60). Brownish with dark tint, fine clay loam, granular (units 0.4 cm in diameter), compacted. Here and there contains silicon rubble, has siliceous powdering, does not effervesce, marked transition by color.

BC₁ 56(60)-76(80) cm. Rusty brown with dark tint, moist, fine clay loam, medium nutty, structureless in places, compact. Includes silicon and limestone rubble in small quantities. Effervesces poorly in places. Transition marked by color.

BC₂ 76(80)-85 cm. Brown with white streaks of limestone, moist, fine clay loam, structureless in part, medium nutty in part, compact. Effervesces, in places violently. Transition abrupt.

C 85-(200) cm. White leached limestone on top, passing to limestone deposit below.

We give below the data on particle size analysis and on certain physical properties of the anthropogenic humus carbonate soils of different ages and the natural humus carbonate soils.

As can be seen from the particle size analysis in Table 1 all the soils are fine clay loams and clay coarse silts. Losses from treatment with HCl, however, are found to be 15 times less in the top horizon of the 100-year-old soil than in the corresponding horizon of the 25-year-old soil. This is due to the considerably greater carbonate content in the young soil in comparison with the old. The sand fraction in the 100-year-old soil is only half that in the 25-year-old soil; the silt content in the former is 69% and in the latter 57%. The amount of clay as well as physical clay, however, is almost the same in both. The foregoing comparison indicates that the weathering of such soil-forming parent material as limestone under the conditions of the region described occurs fairly quickly, although the actual elements of the 25-year-old soil have been changed less than the corresponding elements in the older soil.

As regards particle size, the natural humus carbonate soils are also fine clay loam and clay coarse silt. Their parent material is the same as that of the 100-year-old anthropogenic soil, very stony. Losses from treatment with HCl are very considerable (69%). As has been noted in the morphological description of the soils under consideration they have a granular structure which is most marked in the more mature humus carbonate soil. The data for structural and aggregation analyses according to Savvinov's method in fact indicate that up to 75% of the soil mass is made up of structural units > 0.25 mm in diameter, whereas in the corresponding horizons of the soils ultimate particles > 0.25 mm in diameter make up only a fraction of a per cent or a few per cent (Table 2). This in turn indicates a high degree of aggregation in soils described. If we trace the process of soil structure formation with time we find that in the top horizons the quantity of aggregates > 0.25 mm in diameter in the 100-year-old soil accounts for 83% of the soil mass but for only 73% in the 25-year-old soil. This points to the fairly rapid formation of water stable aggregates.

Comparison of the humus content in the anthropogenic humus carbonate soils of different ages justifies the assertion that the accumulation of humus with time also occurs comparatively rapidly (Table 3). In the top horizon of the 100-year-old soil there is 5.3% humus; in the 25-year-old soil, 8.24%.

We shall see later that the humus in the 100-year-old soil is distributed evenly along the profile, the amount decreasing sharply with depth; in the 25-year-old soil the humus is almost all concentrated in the sod horizon, whereas in the soil-forming parent material its percentage content decreases very sharply.

In the top horizon of the natural humus carbonate soil of mature age the humus content is 5.71%; that is, it only very slightly exceeds the humus content in the top horizon of the 100-year-old anthropogenic soil. The humus amount decreases gradually along the profile but penetrates to a great depth.

The reaction of the soil solution of all three soils compared is weakly alkaline (Table 3). An appreciable content of adsorbed calcium was noted in all the soils described and the accumulation of adsorbed calcium in the top horizons was found to be considerable in comparison with the soil-forming parent material. The somewhat higher content in exchangeable calcium in the young soil is due to the notably larger amount of humus in it, whereas the slight increase in adsorbed calcium in the B horizon of the natural humus carbonate soil is due to the somewhat greater clay content.

As can be seen from the total chemical analysis (Table 4), the amount of CO₂ carbonates in the top horizons of the natural humus carbonate soil and the 100-year-old anthropogenic humus carbonate soil is much less than in the top horizon of the 25-year-old anthropogenic soil. It follows that CaCO₃ has been removed in notably larger amounts from the profile of the natural humus carbonate soil than from that of the 100-year-old and particularly from that of the 25-year-old anthropogenic soils. The discrepancy is due to the different ages of the soils.

Table 2

Structural and aggregate analysis (N. I. Savinnov method) of anthropogenic humus carbonate, buried and non-buried light-grey forest soils (in %)

Profile No.	Soil	Horizon	Depth, cm	Diameters in mm																	
				>10	10-7	7-5	5-3	3-2	2-1	1-0.5	0.5-0.25	<0.25									
				Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet								
111	Anthropogenic humus carbonate, 100-year-old	Asod A ₁	0, 8 12-17	9, 48 20, 14	None None	5, 38 10, 02	None "	10, 55 13, 65	None "	22, 31 24, 70	38, 78 47, 97	16, 04 12, 10	13, 33 9, 42	20, 15 6, 71	75, 12 58, 6	12, 10 10, 5	6, 85 5, 90	7, 61 7, 68	9, 42 4, 53	17, 68 16, 51	
154	Anthropogenic humus carbonate, 25-year-old	Asod	0-6	3, 54	"	3, 31	"	8, 55	"	17, 90	29, 62	14, 54	10, 97	10, 42	16, 90	15, 72	6, 86	7, 81	9, 09	18, 21	26, 56
111	Light-grey forest soil, buried 100 years	A ₁ buried A ₂ B	55-60 72-77	19, 87 18, 26	"	9, 24 13, 36	"	7, 60 11, 27	"	13, 70 18, 99	1, 51 0, 00	9, 90 11, 36	2, 41 0, 16	8, 04 8, 05	11, 73 0, 78	9, 26 6, 87	9, 52 1, 36	4, 69 2, 85	25, 30 17, 91	17, 69 8, 98	49, 53 79, 79
2154	Light-grey forest soil, buried 25 years	A ₁ A ₂	35-40 50-55	19, 82 10, 28	"	7, 46 7, 97	"	5, 69 7, 98	"	9, 64 20, 23	1, 39 0, 28	8, 32 11, 09	1, 45 0, 26	7, 33 7, 99	3, 53 0, 68	10, 90 18, 1	5, 05 1, 22	6, 33 4, 50	24, 42 11, 12	24, 51 19, 83	64, 16 86, 44
184	Light-grey forest soil on heavy blanket loam	A ₁ A ₂	4-10 11-16	26, 65 4, 59	"	9, 70 5, 69	"	8, 05 4, 70	"	12, 16 12, 53	13, 30 5, 68	9, 40 16, 51	10, 04 2, 24	8, 96 20, 77	7, 32 3, 72	11, 21 14, 86	13, 56 7, 36	6, 26 7, 46	13, 08 11, 08	7, 61 12, 89	42, 70 69, 92

Note: Comma represents decimal point.

Table 3

Pro- file No.	Soil	Horizon	Depth, cm	Humus % (ac- cord- ing to Tyu- rin)	pH		Exchangeable cation content				Readily available N	Available P ₂ O ₅	K ₂ O																									
					Salt	Water	Ca	In meq (accord. to Shmuk)	Ca	H				Al + H																								
															In meq (accord. to Sokolov)	In mg/100 g Kirsanov																						
																	According to Tyurin	According to Kirsanov																				
Chemical composition of soils																																						
111	Anthropogenic humus carbonate (young, 100-year-old) on buried light-grey forest soil	A sod A ₁ A ₁ BC A ₁ Fossil A ₂ B B ₁ B ₂ B ₃ C	0-8 12-17 25-30 35-40 55-60 72-77 81-86 90-95 100-105 125-130	5,3 3,15 2,28 1,15 2,24 0,91 0,69 — — — 8,24	7,0 7,2 7,41 8,2 6,72 6,70 6,70 6,61 6,6 6,50 7,0	7,56 7,80 8,0 8,6 7,26 7,52 7,67 7,40 7,5 7,46 7,45	26,80 Not det'd. " 8,16 15,64 Not det'd. 19,16 Not det'd. " 14,21 35,78	0,54 Not det'd. " 0,16 0,31 " 0,38 " 0,28 0,72	None " " " " " " " " " "	24,42 81,10 Not det'd. " " " " " 35,07 Not det'd. Not det'd. Not det'd.	5,0 6,50 6,50 " " " " " 2,5 6,50 Not det'd.	Not det'd. " Traces " " " " " Not det'd. Traces " "																										
													151	Anthropogenic humus carbonate (immature, 25-year-old) on buried light-grey forest soil	A sod BC A ₁ Fossil A ₂ B ₁ B ₂ B ₃ C	15-20 35-40 50-55 60-65 80-85 95-100 125-130 0-8	1,36 1,15 0,65 0,55 — — — 5,71	7,40 6,93 7,72 7,55 6,71 6,0 4,70 4,61 7,1	7,62 7,72 7,55 7,63 6,81 5,60 5,56 7,9	16,48 13,86 Not det'd. 15,66 Not det'd. " 12,33 24,99	0,33 0,28 Not det'd. 0,31 " 0,25 0,50	0,018 0,48 0,475 0,07 4,90 2,31	87,22 17,93	7,0 10,0	Not det'd. "													
																										181	Humus carbonate (mature) on leached limestone	A ₁ A ₁ B BC ₁ C	15-20 35-40 45-50 65-70 100-105	2,21 1,16 — — —	7,21 7,2 7,22 6,80 7,41	7,72 7,55 7,78 7,72 7,41	Not det'd. " Not det'd. Not det'd. Not det'd.	0,58 0,29 0,33	0,32 0,39 1,07 2,55 3,26 3,71 2,18	Not det'd. " "	4,25 0,31	6,7 4,0

ote: Comma represents decimal point.

Note: Comma represents decimal point.

Table 4
Total chemical composition of soils

Pro- file No.	Soil	Horizon	Depth, cm	Ignition losses, %	CO ₂ carbon- ates, %	In %		Fe ₂ O ₃	CaO	MgO	Total, %	
						SiO ₂	Al ₂ O ₃					
111	Anthropogenic humus carbonate (young, 100-year-old) on buried light-grey forest soil	Asod	0-8	9,25	0,40	75,27	12,82	4,25	1,89	3,38	97,61	
		A ₁ '	12-17	Not det'd.	4,03			Not det'd.			—	
		A ₁ "	25-30	4,65	17,08		Not det'd.		3,75	1,43	—	
		BC	35-40	2,22	34,00					3,56	—	
		A ₁ Fossil	55-60	3,97	0,27	78,65	12,41		5,59	1,52	4,51	98,08
154	Anthropogenic humus carbonate (immature, 25-year-old) on buried light-grey forest soil	B ₁ "	81-86	2,11		74,32	15,65	5,69	1,37	2,10	99,13	
		C	125-130	2,77		72,70	17,92	4,75	1,53	2,55	99,45	
		Asod	0-6	25,17	5,70	74,62	12,96		5,30	1,49	2,65	97,02
		BC	15-20	Not det'd.	25,01			Not det'd.				—
		A ₁ Fossil	35-40	2,27	0,18	79,83	12,98		3,19	1,42	4,70	99,12
181	Humus carbonate (mature) on leached limestone	B ₁ "	60-65	2,17		75,68	16,35	4,26	1,25	4,52	99,06	
		C	125-130	1,72		74,92	17,17	4,66	1,01	4,60	99,36	
		Asod	0-8	9,15	0,84	72,52	13,92		4,59	2,96	3,76	97,89
		A ₁ '	15-20	Not det'd.	2,42				Not det'd.			—
		A ₁ "	35-40	"	2,48				Not det'd.			—
184	Light-grey forest on fine clay loam de- posit	B	45-50	3,41	0,36	72,80	13,74	5,84	1,41	3,39	97,18	
		BC ₁	65-70	Not det'd.	1,33						—	
		C	100-105	1,40	45,00				Not det'd.			—
		A ₂	0-4	7,60	None	80,56	12,56		3,76	0,92	4,02	98,82
		B ₁	25-30	2,72	"	75,84	13,34	5,40	0,63	4,00	96,21	
C	135-140	2,11	0,14	78,12	13,98	4,65	0,76	0,74	98,25			

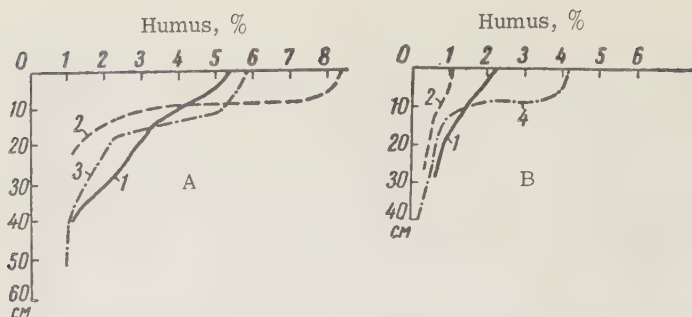


Fig. 1 - Humus content in anthropogenic, natural and buried soils
 A - Anthropogenic (Profiles 111 and 154) and natural (Profile 181) humus carbonate soils. B - Fossil forest soils (111 and 154) and natural (Profile 184) light-grey forest soils.

1 - Profile 111. Anthropogenic humus carbonate (100-year-old soil) on buried light-grey forest soil. 2 - Profile 154. Anthropogenic humus carbonate (25-year-old soil) on buried light-grey forest soil. 3 - Profile 181. Humus carbonate (mature soil) on leached limestone. 4 - Profile 184. Light-grey forest soil on fine clay loam deposit.

The total chemical analysis also reveals some biological accumulation of calcium and magnesium in the top horizons of the natural humus carbonate and 100-year-old anthropogenic soils.

The humus curves for the 100-year-old and mature soils (Fig. 1) are sufficiently similar. The corresponding curve for the 25-year-old soil diverges sharply from these, showing that the distribution of humus along the profile of the younger soil, which has not been completely formed, is uneven.

The pH, adsorbed calcium and clay curves for all three soils differ little from one another, although a glance at the graphs will show that the solution reaction is formed at a much faster rate in the young soils as compared with the accumulation of humus, adsorbed calcium and clay in them (Fig. 2).

In general, it can be noted that the 100-year-old humus carbonate soil differs little from the mature humus carbonate soil.

The buried light-grey forest soils (Profiles

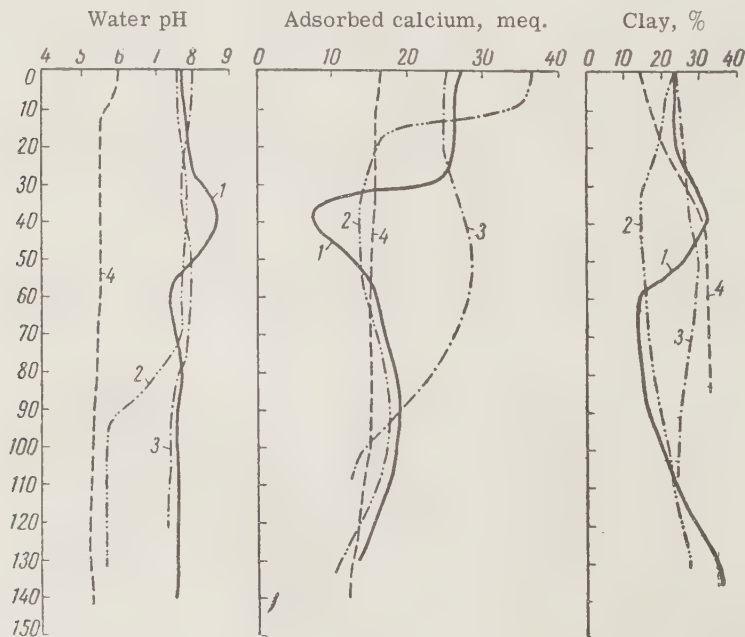


Fig. 2 - Curves of pH, adsorbed calcium and colloidal clay fraction in soils (key as for Fig. 1).

Humus content and composition in different soils (according to Tyurin in Ponomareva's modification), in % of total C content

Pro- file No.	Soil	Horizon	Depth, cm	C Con- tent in humus (accord- ing to Tyurin)	Humic Acids			Total	Fulvic acids				Total all frac- tions	Insol- uble residue	Humic acids	Humic acids	Insolu- ble residue	
					Fractions				Fractions									
					1	2	3		4a	1	2	3						4
141	Anthropogenic humus carbonate (young, 100-year-old) on purified light-grey forest soil	A ₁ Fossil	55—60	1,30	0,55	34,55	6,12	41,22	2,56	0,72	2,54	5,63	15,68	27,13	68,35	31,63	1,52	1,30
154	Anthropogenic humus carb. (immature, 25- yr-old) on purified light-grey forest soil	A ₁	35—40	0,667	1,17	22,60	7,72	31,49	2,33	0,70	4,05	2,73	26,57	36,38	67,87	32,12	0,86	0,98
184	Humus carb. (mat.) on leached limestone	A ₁	5—10	1,454	8,53	41,61	3,05	23,19	8,08	17,51	2,63	7,20	43,55	48,97	72,16	27,85	0,47	0,83

Note: Comma represents decimal point.

111 and 154) have been described previously. For purposes of comparison we shall describe the profile of light-grey forest soils bedded naturally on a fine clay loam deposit.

Light-grey forest soils have developed on lower parts of slopes with a gradient of 4° to 10°-18°; they are more commonly found on steeper slopes. These soils are at present mainly under pasture or small forest areas.

Profile 184. Left-hand slope to Vdovitsa valley.

Gradient 10°-17° to NE. Microrelief, knolls, hollows. Vegetative cover includes Alopecurus pratensis, Poa angustifolia, Trifolium repens, Brunella vulgaris, small birches (Betula verucosa), low quality pasture.

A_{sod} 0-4 cm. Grey, dry, medium clay loam, granular to silty, bound with roots. Transition gradual.

A₁ 4-11 cm. Grey, slightly moist, fine clay loam, silty to small blocky structure, comparatively loose, some roots. Transition marked by the appearance of siliceous powdering.

A₂ 11-16 cm. Grey, whitish, slightly moist, fine clay loam, silty to platy structure, friable in places, slightly compacted in others. A great deal of siliceous powdering. Transition gradual.

A₂B 16-22 cm. Brownish with abundant siliceous powdering, moist, fine clay loam, small-blocky, compacted. Transition in the form of tongues of siliceous powdering, abrupt.

B₁ 22-34 cm. Brown, with siliceous powdering, moist, fine clay loam, nutty, compacted. Transition gradual.

B₂ 34-51 cm. Brown, with pockets of siliceous powdering, moist, fine clay loam, coarsely nutty, compact. Transition gradual.

B₃ 51-83 cm. Brown, with dark coating on faces of structural units, wet, fine clay loam, coarsely nutty, compact, with siliceous powdering. Transition gradual.

BC 83-106 cm. Brown, with dark coating on faces of structural units, damp, fine clay loam, coarsely blocky (units 5 cm in diameter) with white powdering on faces of structural units, compact. Transition gradual.

C 106-(145) cm. Brown, with yellowish tint, damp, fine clay loam, lumpy, compact.

Examining the analysis material we find that in the light-grey forest soil which has been buried for a hundred years and in the naturally bedded light-grey forest soil the silt fraction (particularly the coarse silt fraction) accumulates in the upper horizons (Table 1). The amount of clay increases with depth in both the buried and the non-buried light grey forest soils. In all three soils losses from HCl treatment are slight. Except in the top parts of the A₁ horizon of the buried soils where there are admixtures of leached limestone, no effervescence from HCl

is observed anywhere in the profile.

While the particle size analysis data show that only a few parts of a percent to 1.5% of both the buried and the normal light-grey forest soils are made up of particles > 0.25 mm in diameter, the structural aggregate analysis (Table 2) show that the number of water-stable aggregates > 0.25 mm in diameter is fairly high (36%-57%) particularly in the top horizons of these soils. The content in water-stable aggregates > 0.25 mm in diameter sharply decreases along the profiles of all three, and especially of the buried soils. The 100-year-old buried soil contains a greater number of such aggregates than the 25-year-old buried soil. It follows that in the course of several decades the number of water-stable aggregates > 0.25 mm in diameter has increased at a more intensive rate in light-grey forest soil which has been buried for a hundred years and subjected to more prolonged influence than the anthropogenic humus carbonate soils. This is probably directly connected with the increased quantity of adsorbed cations and particularly adsorbed calcium in the 100-year-old buried soil.

Comparison of the humus amount in the normal and buried light-grey forest soils shows that the humus content in both is much the same, particularly if their corresponding horizons are compared (Table 3). If one proceeds from the humus content in the same profile of the different soils, the great difference between soils of the same type, according to whether they are

natural or buried, becomes obvious. The humus group composition data (Table 5) show that the humic acid fraction as a result of sesquioxides (mainly Fe_2O_3) in the light-grey forest soils has greatly decreased, during the time in which they have been buried under humus carbonate soils, in comparison with the corresponding fraction of the humic acids in the non-buried soils. Conversely, the humic acid fraction as a result of calcium has become several times greater in the buried light-grey forest soils as compared with the non-buried light-grey forest soils. The humic fraction associated with stable R_2O_3 and clay has correspondingly increased.

The amount of all the fulvic acid fractions except the fraction associated with clay and stable R_2O_3 decreases the longer the light-grey forest soils are buried, particularly sharply in the case of the fulvic acid fraction connected with the first fraction of the humic acids. The amount of insoluble residue is somewhat higher in the buried light-grey forest soils. The ratio of humic acids to fulvic acids is several times higher in the buried soils than in the non-buried ones.

It should be noted that the humus content in the light-grey forest soils has decreased in proportion to the time they have been buried. As can be seen, however, from what has been said previously, not all the component parts of the humus decrease to the same extent; in the buried light-grey forest soils the humic acid fractions increase relatively to the fulvic acid fractions.

Table 6
Water soluble carbonate and bicarbonate content, %

Profile No.	Soil	Horizon	Depth, cm	Dry residue, %	HCO_3
111	Anthropogenic humus carbonate (young, 100-year-old) on buried light-grey forest soil	A_1 buried	55—60	0,066	0,02
		A_2 B "	72—77	0,05	0,01
		B_1 "	81—86	0,05	0,006
		B_2 buried	90—95	0,05	0,011
		B_3 "	100—105	0,04	0,01
		C "	125—130	0,07	0,015
154	Anthropogenic humus carbonate (immature, 25-year-old) on buried light-grey forest soil	A_1 buried	35—40	0,06	0,015
		A_2 "	50—55	0,056	0,014
		B_1 "	60—65	0,026	0,01
		B_2 "	80—85	0,02	0,006
		B_3 "	95—100	0,02	0,004
		C "	125—130	0,014	0,004
184	Light-grey forest on fine clay loam deposit	A_d	0—4	0,03	0,011
		A_1	5—10	0,02	0,005
		A_2	11—16	0,02	0,005
		B_1	25—30	0,012	0,004
		B_2	40—45	0,02	0,003
		B_3	65—70	0,02	0,004
		C	135—140	0,024	0,033

Note: Comma represents decimal point.

The reaction of the buried light-grey forest soils is almost neutral, except for the two lower horizons of the 25-year-old buried soil, where it is weakly acid (water suspension pH 5.6; Table 3). The reaction of the light-grey buried forest soil is weakly acid. The influence of the anthropogenic humus carbonate soils in modifying the reaction of the soil solution is consequently very great. The degree of modification in the reaction of the 25-year-old buried soil, however, did not prove to be considerable throughout the profile. The weakly acid reaction is retained in the deep horizons of this soil. There is probably very little adsorbed hydrogen in the 100-year-old and in the other part of the profile of the 25-year-old light-grey forest buried soil, but in the lower part of the profile of the latter, where the reaction of the soil solution becomes weakly acid, there is a good deal of adsorbed hydrogen, although much less than in the natural light-grey forest soil (Table 3).

Adsorbed calcium accumulates in the B₁ horizon of the buried light-grey forest soils owing to the high clay content in this horizon. There has been no marked increase in the adsorbed calcium in the buried light-grey forest soils as compared with the non-buried soils.

It is clear from the bulk analysis figures that in the buried light-grey forest soils the calcium and magnesium amount has increased considerably in comparison with the non-buried light-grey forest soil (Table 4). Biological accumulation of calcium and magnesium was noted in the top horizons of all three soils.

During the time the light-grey forest soils have been buried the total amount of biocarbonates and carbonates passing into water extract from the buried light-grey forest soils has slightly increased as compared with the non-buried soils, except in the lower part of the 25-year-old buried soil, where the salt composition has not noticeably altered. The HCO₃ content in buried light-grey forest soils (except for the lower part of the 25-year-old buried soil) has particularly sharply increased under the influence of the anthropogenic humus carbonate soils (Table 6); there is no CO₃⁺⁺ in them.

The combined humus, pH and adsorbed calcium and clay curves graphically show the change that has occurred in the light-grey forest soils in the process of their being buried (see Fig. 2).

Conclusions

1. A humus carbonate soil with a fully developed profile, suitable for plowing, well structured and possessing available nitrogen and phosphorus has formed over a period of 100 years on weathered and leached limestone parent material in a broad-leaved forest sub-zone.
2. The anthropogenic humus carbonate soils have to a large extent transformed the light-grey forest soils buried underneath them in the course of a few decades (25-100 years). The humic acid content in the buried soils has increased in comparison with the fulvic acid amount and the reaction of these soils has become slightly alkaline.

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PHYSICAL EVAPORATION OF MOISTURE FROM SANDS AND SANDY SOILS

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The article deals with the quantitative loss of moisture between minimum field moisture capacity (FC) and wilting moisture (WM) under conditions that exclude desiccation. The hypothesis that moisture is stable when equal to FC, formulated by Rotmistrov (10), Kossovich (5) and with greater precision by Lebedev (8), has recently been seriously criticized (1, 2, 3, 9). It has been shown that suspended moisture in clay loams can be subject to physical evaporation from FC to a definite level lying in the main between 60%-70% of FC and called by Abramova (1) "the moisture at which the capillary connection is broken" (MBC). This very important phenomenon in the dynamics of moisture should be reflected in the agriculture of arid regions in three main trends: 1) improvement of structure as the factor that reduces physical evaporation in all seasons; 2) maximum use of winter crops that reduce physical evaporation in the early spring; and 3) in relation to black fallow, which loses its main feature as a moisture accumulator in the summer, causing fallowing to be pointless at this time, especially on structureless soils.

Different results have been obtained in experiments with sands. It has been concluded from Oreshkina's experiments (2) that physical evaporation is not present in sands (excluding

the upper 20-25 cm). The work was carried out in packed columns. Lebedev (8) came to the same conclusion. Whereas Oreshkina only applied this feature to sands, Lebedev extended it to all types of soil. The field capacity of the sands taken by Lebedev and Oreshkina for their experiments was less than 3%, i.e., they can be classified as being of low capacity (by Gael's classification, 4). Medium and high capacity, the FC of which increases to 8%, have not as yet been studied.

Experimental work on the Tera-Kuma sands showed that a part of the FC moisture in medium and high capacity sands in horizons below 20 cm is lost to physical evaporation and that the conclusion of Lebedev and Oreshkina only holds for low moisture capacity sands.

Materials from observations of moisture dynamics in open sands of the Bazhigan, Tera, Tereklin and Kuma massifs and a virgin steppe area of the Bazhigan massif, which has been described in a separate paper (7), were used to determine physical evaporation under various conditions in the area between the Tera and the Kuma. In the latter case a 15 x 15 m plot was kept free of weeds. Thus, the studies were in essence made on "black" fallows.

Table 1

Changes in moisture contents at different seasons of the year in different sands of the Tera-Kuma region from data for 3-6 years, %

Name of the sand massif	Moisture character- istic of the 0-100 cm layer			March			July			September		
	FC	MBC	MBC as % of FC	Depth, cm								
				0-2	50	100	0-2	50	100	0-2	50	100
Tera, northeastern part	3,3	3,0	91	2,7	3,4	3,0	0,3	3,1	2,9	0,4	3,0	3,0
Tereklin	5,9	4,6	78	4,7	6,4	6,5	0,8	4,8	4,4	0,9	4,9	4,4
Kuma	5,5	4,7	86	4,3	5,8	5,7	0,7	4,8	4,7	1,0	4,8	4,9
Bazhigan	6,1	4,8	79	5,1	6,5	6,5	1,1	4,6	4,9	1,0	4,8	5,0
Bazhigan sandy loam area	11,0	6,3	57	17,5	12,6	10,0	1,2	6,5	6,3	2,6	6,7	5,9

Note: Comma represents decimal point.

Moisture content was determined to a depth more than 4 m on the Bazhigan sands monthly throughout the year and by seasons on the other sands. The surface of the areas was not isolated and precipitation entered the soil profile freely.

It is clear from Table 1 that losses of moisture after its supply in the cold part of the year occur on the fine-grained silt, medium moisture capacity Tereklin, Kuma and Bazhigan sands and sandy loams. On the other hand, the medium-grained low moisture capacity Tera sands scarcely dry out at all, except in the upper 15-20 cm.

The most active loss of moisture from the spring season on medium moisture capacity sands takes place between the 11th and 30th of April, when the temperature of the air and the upper soil horizons rises to 8°-12°C. In the next 2-3 weeks the moisture of a 1-2.5 m layer of sand decreases from 6% (FC) to 4.6-4.8%. After this, evaporation ceases and the remaining moisture contents stay practically unaltered throughout the summer.

Only the upper 10-20 cm dry out more intensively, except that coarse sands dry out to a slightly greater depth. Summer precipitation does not significantly affect the total moisture content, since it evaporates in 6-12 days, twice as rapidly as in the spring, even if it penetrates

to a depth of 60-70 cm. This can be clearly seen on the open Bazhigan sands (6) as well as on sandy loams (Fig. 1). Total soil moisture contents after the evaporation of precipitation are the same as before the rain (approx. 5% in medium moisture capacity sands and 6%-7% in sandy loams).

Thus, the amount of water evaporated from the open medium moisture capacity sand was 14%-22% of FC. Residual water content was stable with time and depth. Summer precipitation was not held at FC level and caused only a temporary increase in its value.

Evaporation of water is considerably lower on coarse-grain low moisture capacity sands than on medium moisture capacity sands. Table 1 shows that the sands in the northeast of the Tera massif lose only 9% of FC in the course of the year, which is here equal to 3.3%, and that even this slight loss of water is absent from sands with a lower moisture capacity, as can be seen from the experiments of Oreshkina and Lebedev.

The processes of evaporation on the coarse sandy loams of the Bazhigan massif are extremely interesting. A plot left to fallow in October, 1953 was wetted to a depth of 40 cm (Fig. 1) in the course of the ensuing winter. Even deeper layers, down to 110 cm, were

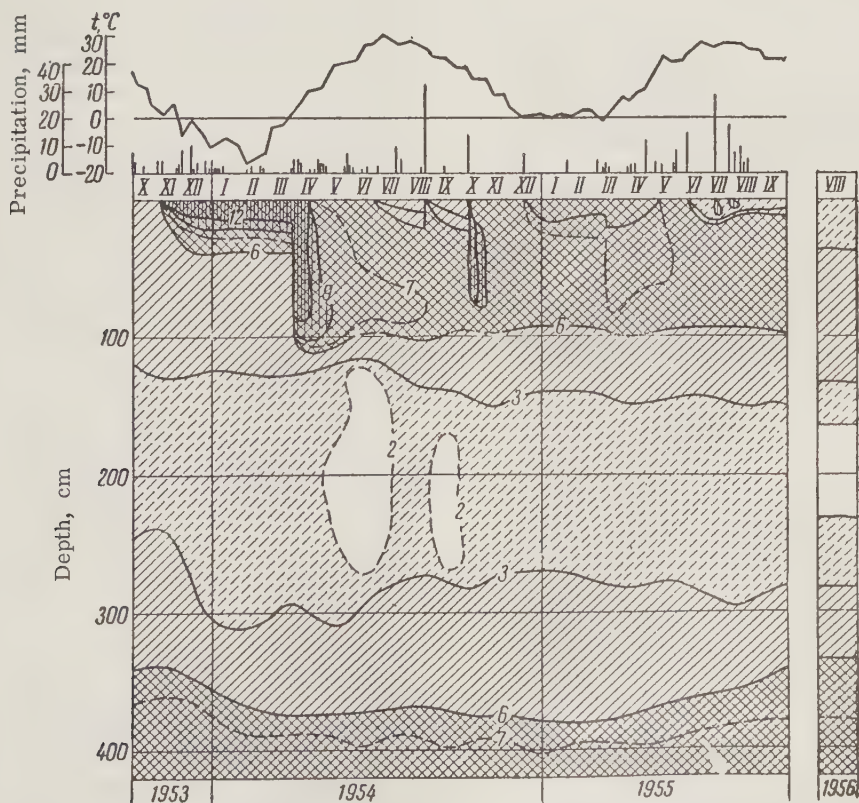


Fig. 1. - Moisture dynamics of a fallow sandy loam plot in the Bazhigan sand massif. Isopleths given in percentages of the weight of absolutely dry soil.

Table 2

Water losses in April, 1954 and 1955 on sandy loam plots with different conditions of soil surface

Place of observation	Precipitation	
	1954	1955
	19 mm	30 mm
Fallow plot	-44 ^a	-15
Virgin steppe plot (Projected covering of 70%-80%)	-28	+4
Plantation of white acacia (14 year, height 10-12 m, crown density 70%-80%)	-4	0,0

^aThe minus sign indicates a reduction in totals of moisture content and the plus sign an increase.

Note: Comma represents decimal point

wetted at the end of March after extensive thawing of the snow. Average moisture of the whole wetted horizon was up to 11% (FC). Drying started in the second half of April and reached 3 mm per day by the end of the month. It should be noted that evaporation proceeded considerably more rapidly on fallows than on plots covered with grasses or in wooded area (Table 2), mainly owing to the greater heating of the unprotected surface.

Moisture losses from evaporation were considerably reduced in the second half of May on the fallow plot and an extremely stable moisture, averaging 6.3%, was established in soil. Summer precipitation only affects total water content in the upper horizons and even if it penetrates far deeper (October, 1954) its effect is limited to 2 weeks. After this the quantity of moisture is again established at the MBC level. In the same way as on medium moisture capacity sands, summer precipitation is incapable of maintaining content of water at the FC level.

Secondary stable wetting of the soil began in December. The moisture penetrated to a depth of 30 cm during the winter and to a depth of 80 cm after the snow thawed. The lesser depth of wetting is due to the insignificant amount of precipitation in the cold months of 1954-1955 (80 mm as against 140 mm in 1953-1954).

In 1955 the MBC had been reached by the beginning of May and was maintained throughout the entire warm period. Elimination of weeds was terminated in September, and in August of the following year the amount of water in a 350 cm layer was close to that of the "wilting content" and the same as on an adjacent virgin steppe plot. The introduction of a new factor—vegetation—into the experiment greatly altered the moisture dynamics.

It is important to note the following feature of our experiment: 2 year fallowing of sandy loam did not destroy the "wilting" dispulsive horizon, owing to the existence of evaporation processes. Analysis of FC and MBC shows that the ratio between these quantities approaches unity on coarse soils as the texture be-

comes coarser and the moisture capacity decreases (Fig. 2).

The existing material on the Bazhigan open sands, which are thin (1-2 m) friable wind deposits on multi-stage ancient alluvial sandy loams, shows that water losses from evaporation are to be observed, according to the preliminary data, down to at least 2 m. Figure 2 shows that when the sands are underlain by sandy loams at a depth of 80 cm and above, the latter do not dry out and their total moisture contents are maintained at around the FC level throughout the year. The overlying layer of sand loses water.

Without dealing in particular with the question of the availability of moisture between FC and WM, it is necessary to indicate that the water requirement curve for various cultivated plants and natural phytocoenoses on the medium and high-moisture capacity Tera-Kuma sands shows that under these conditions the utilization of soil moisture proceeds with equal intensity in the range from FC to WM, but that when WM is reached moisture losses fall sharply. This confirms Rode's conclusion (2) that a moisture that slows down growth in sands is close to the wilting moisture.

The nature of the water requirement curve for a 15-year well developed plantation of white acacia given in Figure 3 shows that when total moisture content falls to MBC and below there is no interruption in the utilization of soil moisture by plants. The main plant growth occurs between mid May and mid June, although the moisture in the soil decreases in this period from MBC to WM.

A pattern similar to moisture loss is to be observed in many other fully grown plantations on the Tera-Kuma sands and on plots covered with well-formed grasses with a developed root system that normally extends throughout the soil layer wetted in the autumn and winter (7). One cannot therefore agree with Ryzhov (11) that these conclusions are "a hearkening back" to American conclusions that water is equally available in the range FC to WM. My experimental data lead to the following conclusions.

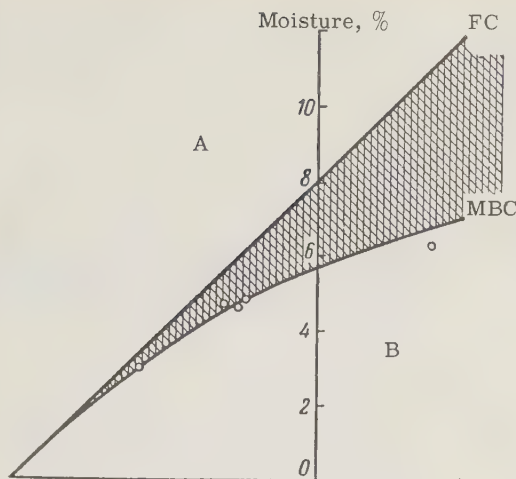


Fig. 2. - Ratio between FC and MBC in coarse structureless soils. Constructed from the data in Table 1 with allowance for Abramova's material on microstructured coarse clay loams.

A - sands, B - sandy loams.

Sands and sandy soils devoid of vegetation and moistened to FC are able to lose a certain amount of moisture during the summer owing to evaporation from the horizons below 10-20 cm. The amount of this loss depends on the moisture capacity of the sands. On low moisture capacity sands (FC < 4%) up to 10% of the field moisture capacity is lost, this figure decreasing rapidly as moisture capacity is reduced. On medium moisture capacity sands (FC 4-6%) losses reach 20%-25% of FC and on high moisture capacity sands (FC 6%-8%) more than 20%-25%. The amount of moisture lost to evaporation reaches 42% of FC on coarse sandy loams. Summer precipitation in arid districts cannot maintain moisture at the FC level.

One can assume from the nature of moisture dynamics in the coarse textured soils and silty-fine sands of the region between the Tera and the Kuma Rivers that moisture loss in the deep horizons is mainly due to its movement in liquid form into the zone of direct evaporation (upper 10-20 cm). The dynamics of this process have been revealed by countless experiments with movement indicators conducted by workers at the V. V. Dokuchayev Soil Institute.

The movement of water to the evaporation zone in sands and sandy soils is extremely intensive. When the temperature of the upper horizons is higher than 8°-12°C for 2-3 weeks, the total moisture contents decrease from FC to MBC. Up to 3 mm of water are lost in 24 hours. Evaporation is 2-3 times less intense on plots protected by vegetation than on fallow.

Preliminary data show that the depth from which moisture can move is up to 2 m in fine-grain-silt medium moisture capacity sands.

In districts of insufficient moisture the de-

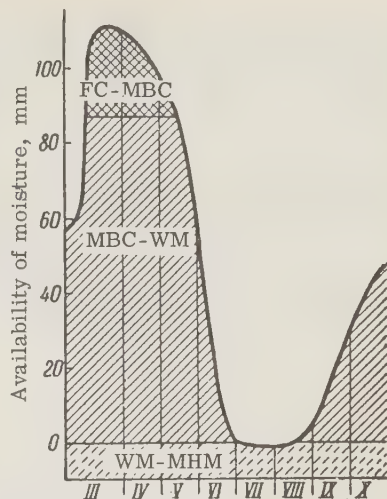


Fig. 3. - Change in total moisture contents in the spring wetting of soil layer (0-130 cm) in a 15-year-old plantation of white acacia on the Bazhigan sands (non-leaching type of water regime).

termination of MBC in coarse-textured soils can be conducted in the summer on fallow plots previously wetted in the spring after a 2-3 week period without rain.

In root inhabited coarse-textured soils, moisture is utilized with equal intensity throughout the range between FC and WM.

The existence of evaporation process in coarse-textured soils reduces the value of black fallows as accumulators of moisture. To improve the use of agricultural land, plowing for winter crops should be carried out in the first half of the summer after harvesting early crops. Summer precipitation will be absorbed by the soil on fallows of this kind owing to their low moisture content.

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EXTENT OF SOIL EROSION IN RELATION TO THE MAIN METHOD OF TILLAGE

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We have made a prolonged study of various methods of preventing water erosion on the Spartak, Diktatura and Plavskiy sovkhoses in the Tula region. Particular attention has been paid to the protection of fields left without perennial grasses or winter grain crops during autumn and spring. In this case the basic soil tillage is of decisive importance. One of our experiments included: 1) Plowing across the slope using a coulter; 2) The same, along the slope; 3) Listing across the slope; 4) Plowing without moldboard across the slope; 5) Discing to a depth of 7-9 cm; 6) Stubble, i. e., the field was not worked in the autumn, and 7) Discing-listing across the slope.

All types of cultivation were carried out to a depth of 22-25 cm. These sovkhoses are situated in the northern spurs of the Central Russian Upland at 220-240 m above sea level. The relief is typically eroded, i. e., formed by the activity of running water. Gullies and ravines are typical relief forms. The watersheds are rounded and narrow crests. Slopes are short (50 m on the Plavskiy and Diktatura sovkhoses and 480 m on the Spartak sovkhos), convex and with a gradient of 16% on the Plavskiy and 14% on the Diktatura and Spartak sovkhoses. The average level of local erosion is 75-100 m and the extent of the gully-ravine network is 0.4-0.5 m/km². The soils are leached chernozems containing 6%-8% of humus in the 50-75 cm humus horizon. The parent materials are loess-like carbonate clay loams. The experiments were conducted on southerly slopes in all the sovkhoses. We found that the principal soil erosion in the Tula region occurs in the spring, but may also take place in the summer and autumn and even in December. We found considerable erosion on December 18, 1952, for example.

In trying to prevent erosion in the Tula region, one should aim to reduce or, if possible, totally suppress spring runoff. In our opinion this can be done by creating basins on the surface of the soil to receive all the melt water. All measures that help to retain heat in the soil at the onset of thawing are of fundamental importance to preventing erosion, since there is a relationship between the amount of water that soaks through the soil in the spring and the retention of heat. Other conditions being equal, the retention of heat is directly related to the thickness of the snow cover. Measures should

therefore be taken to retain the first snow.

Snow begins to fall in the Tula region in the middle of November, but a continuous snow cover is only established in the second half of February; mean diurnal air temperature becomes negative from the middle of November. Heat loss and the freezing of the soil mainly occur in the period between the establishment of a negative mean diurnal temperature and the establishment of persistent snow.

To confirm our statements, special duplicate experiments were established on an area of 33 ha in 1953-1954. In one treatment of the experiment, small straw bundles 45-50 cm high were laid out at a rate of one to every 2 x 2 m area on October 20; in the other, snow shields (1.5 m high and 1 m wide, distributed every 8 x 8 m) were employed as soon as there was persistent snow; in the third there was no snow retention; in the fourth the snow was retained by straw bundles and snow shields. The first snow fell on November 12.

On December 1, there was a 15-20 cm layer of snow on the plot with straw bundles, whereas snow was only retained in the furrows on plots without straw; in the first case the soil had frozen to a depth of up to 20 cm and in the second of up to 80 cm.¹ On January 20, when the snow lay thick on all the fields, it was 40-50 cm on the field with straw bundles and only 15-20 cm on those without bundles. The soil had frozen to a depth of 35-40 cm in the first case and 100-120 cm in the second. On January 20, the snow was first retained with snow shields and this was repeated on February 20, March 1, and March 10. By the time the snow began to thaw we accumulated as much snow on the plots without bundles of straw as on those with them. After January 20, the straw bundles no longer retained snow, since they were covered by it. When thawing began (March 15) the total water content in the snow was (in metric tons/ha): a) 875 on plots where the snow had been retained by straw bundles alone; b) 1013 on plots with straw bundles and snow shields; c) all on plots with snow-shields alone; and d) 576 on plots without snow retention.

¹On this day the temperature at the surface of the snow was -15°C, and at the surface of the soil -6°C in the first instance and -14°C in the second.

By the onset of thawing the ground had frozen to a depth of 40-45 cm where the snow was retained by straw bundles or by straw bundles and snow shields, to 130-150 cm where it was retained by snow shields, and to 145-160 cm where there was no retention of the snow. The depth of freezing was determined by digging 5 pits in each treatment.

The soil had completely thawed by March 23, on the plots with straw bundles, i. e., before the snow had gone; on the plots where snow was retained by snow shields alone or not retained the frozen layer was 60-75 cm thick when the snow had melted (March 28). The soil moisture (Table 1) in 10 cm layers to a depth of 150 cm was determined before harrowing.

The moisture of a 1-1/2 m layer of soil where snow had been retained by shields only exceeded that of a field on which snow had not been retained by 0.4%, but 22 metric tons/ha of fine earth had been eroded from the first plot as against only 11 metric tons/ha from the second, i. e., half as much. The reason for this is that 1.4 times more snow was accumulated by the shields than on the field on which snow was not retained, but the soil was frozen to practically the same depth in each case, as a result of which more water flowed from the first plot and there was more erosion.

The picture is completely different on plots where the snow was retained from the autumn by straw bundles. Retention of the first snow in a continuous layer preserved the heat in the soil, protected it from deep freezing and created the conditions in which it could thaw before the snow had gone. This considerably reduced erosion. Erosion from these plots was 6 metric tons/ha, i. e., 3.7 times less than on plots where snow was retained by shields and 2.1 times less than on plots on which snow was not retained.

The soil moisture of a 1-1/2 m layer was 2.1%-3.3% higher where snow was retained by straw bundles and by straw-bundles and snow

shields than where it was retained by snow shield alone and 2.5%-3.7% higher than on plots without snow retention.

In this experiment we attempted to prove that snow could be evenly accumulated on a field at an early stage and that heat could thus be retained in the soil. If snow is unevenly accumulated erosion may be increased. We have as yet only one means of retaining heat in the soil and that is by covering the field with a layer of snow at the earliest possible moment. This can only be done if the fields are prepared for snow retention in the autumn before snow falls.

Considerable labor is involved in distributing straw bundles and board shields on the fields. It is more economically advantageous to create a local relief on the surface of the field by plowing to bring about maximum accumulation of the first snow. This can be largely effected by ridging and basin-listing.

Listing can be done by substituting lengthened moldboards on the first and third furrows of a four-furrow plow. The plow then forms two ridges 18-22 cm high and 2 furrows 18-22 cm deep (Fig. 1). The ridges and furrows run across the slope. Basin-listing is also effected with a lister plow equipped with a special damping device. Basin-listing divides the surface of the field into closed basins 1.2-1.5 m long, 50-60 cm wide and 18-22 cm deep. The dimensions of the basins are regulated in relation to the amount of snow that accumulates on the fields by the onset of thawing. Basin-listing (Fig. 2) is carried out across the slope. Direction is, however, not as important as in listing. A slight deviation from the horizontal does not lead to the concentration of water, since all the melt water is accumulated in the system of closed basins. Basin-listing forms more than 11,000 basins per ha with a total capacity of approximately 2,000 m³. This capacity is quite adequate to cope with all the melt water.

Ridging and basin-listing of local relief has a marked influence on wind conditions in the

Table 1

Soil moisture on April 26, 1954 in relation to measures undertaken to retain the snow (Plavskiy sovkhoz, Tula region), % absolutely dry soil

Depth, cm	Without snow retention	Snow retention			Depth, cm	Without snow re- tention	Snow retention		
		By snow shields	By straw bundles	By straw bundles and snow shields			By snow shields	By straw bundles	By straw bundles and snow shields
0-10	26,2	25,1	26,3	25,8	90-100	19,5	22,6	25,1	24,9
10-20	33,3	31,8	35,6	34,9	100-110	19,7	20,5	20,2	22,6
20-30	32,4	34,3	37,3	38,1	110-120	18,9	19,4	19,6	20,3
30-40	28,6	30,5	30,1	34,5	120-130	17,4	18,2	20,5	20,2
40-50	26,9	27,6	29,4	33,6	130-140	16,1	17,3	21,3	20,1
50-60	27,8	28,7	29,9	31,2	140-150	16,8	16,9	18,6	20,7
60-70	25,8	24,1	28,5	30,7	Mean mois- ture con- tent of the entire layer	23,5	23,9	26,0	27,2
70-80	22,4	21,3	21,3	25,4					
80-90	20,8	21,5	26,4	25,7					

Note: Comma represents decimal point.

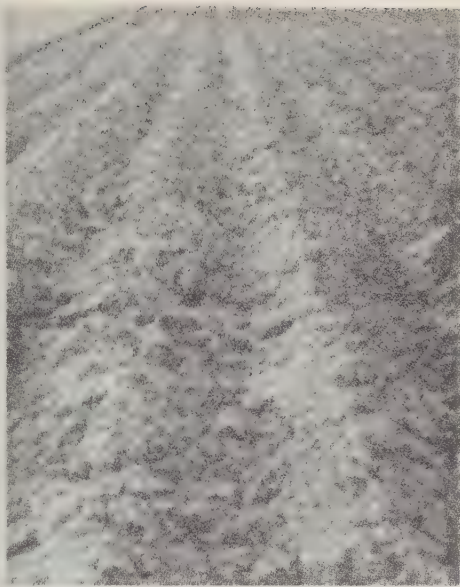


Fig. 1. - Listing.

fields with more or less level microrelief, the soil at the bottom of the furrows and basins is therefore less deeply frozen in the winter and thaws completely before the snow goes in the spring. After the snow has gone there are hollows in the fields which can clearly be seen from the middle of the land around the watershed on fields with more or less level microrelief; their depth reaches 10-15 cm and 20-25 cm where there are channels. They are normally straight and without meanders.

Ruts only begin to be noticeable on listing from the middle of the gully net area; here they are not continuous but broken up by the furrows and consist of washed-away ridges. The flow of water from ridged fields is very meandering. Ruts are not formed on slopes with a gradient of 12%-16% on basin-listed fields. By using small red floats, we measured the distance travelled, duration of motion and number of times soil particles were held up within the field. Four-hundred floats were put into running water 80 m from the head of a gully (200 on listing and 200 on ordinary plowing). The floats thrown into the rivulets on the field plowed with a coulter travelled 83 m on average in 40 seconds and reached the neck of the gully. On the ridged field they travelled 2364 m in 41



Fig. 2. - Basin-listing.

round atmospheric layer. Eddies are formed at the furrows and basins, the wind loses its force and transporting capacity and the snow settles and gradually accumulates. The first snow does not thaw on ridged or basin-listed fields but builds up on them. These fields are completely covered by snow 1.5-2.0 months earlier and have 30%-35% more snow than on

hours (allowing for stopping). On the ordinary coulter plowed field the floats were not held up at all, but on the ridged field each float stopped 238 times on the average.

To pass from the gullied area into the hydrographic net a soil particle on the ridged field had to follow an extremely tortuous path of

2364 m, which was 28.5 times longer than that for a similar soil particle on the ordinary plowing; this took 41 hours, i. e., 3900 times longer than on the ordinary plowing and there were 238 stops. It is evident that not all soil particles will overcome such obstacles and that the greater part will settle at one or other of the obstacles. Surface particles are most likely to be eroded from the field. To study this question we set up the following experiment: floats were arranged in a checkrow pattern on the ridge, gullied area and center slope of ridge and basin-listing and also on land coulters plowed in the autumn before the frosts. Nine-hundred floats in all were used: 300 on the ridged areas, 100 each on each type of plowing, 300 on the center slope and 300 on the gullied area. All the floats were numbered and a prominent marker was placed by each. The number of the float was recorded on the marker. The disposition of the floats (type of plowland and position on the slope) was noted. After the snow had melted and the soil dried out a thorough search was instituted. All 100 floats were recovered on the ridge sector at various distances from their positions in the autumn. Of the 100 floats positioned on the center slope in the autumn, 37 were in the gullied area, 22 were outside the field in the hydrographic net and only 41 were found in position. None of the latter was by its marker, i. e., where it had been placed in the autumn — all had moved by between 20 cm and 10 m.

Of the 100 floats placed in the gullied area of the slope, 49 were found in position and 51 had been carried outside the field into the hydrographic net. Thus, 227 out of 300 floats scattered over a ridged slope remained in the field and 73 were carried outside: this indicates that 24 out of every 100 surface soil particles may be eroded during the spring thaw and carried into the hydrographic net.

All 227 floats were found in microdepressions

in the field, i. e., where soil particles had settled in ridging. Only 16 of the 100 floats scattered on the ridge section of the coulters plowed field were found; 11 were found on the center slope and 9 in the gullied area; 64 were carried outside the field. Thus, the soil was not eroded from the ridge sector when the ground had been ridged, but only moved from place to place, whereas only 20% of the particles remained in place on the coulters plowed field and the remaining 80% had been eroded; 10% of the latter had settled on the center slope and 10% on the gullied area, while 60% had been carried into the hydrographic net.

Only 10 of the 100 floats on the center slope remained in place: 12 were found on the gullied area and 78 were carried outside the field. Consequently, 90% of the surface soil particles were eroded from the coulters plowed center slope during the spring thaw, 12% of these were retained in the gullied area and 78% were carried outside the field. When this sector of the slope was ridged, 59% of the particles from the soil surface were eroded, of which 37% were retained in the gullied area and only 22% were carried away. On the gullied area only 3 of the 100 floats scattered in the autumn were found and 97 had been carried into the hydrographic net, i. e., almost all the surface soil particles were removed from the field into the gullies and ravines in coulters plowing; 51% of the soil particles were lost in ridging. Thus, of 100 particles on the surface of the soil, 24 could be carried away in the spring when the field had been listed and 80 when it had been coulters plowed. Only 9 of the 300 floats scattered on the basin-listed field where not located in the field. These floats had not moved from one area to another; the 9 missing floats had been carried away from the gullied area, i. e., when the field had been basin-listed only 3% of the surface soil particles might be carried away by thaw waters. Between 1948 and 1954 we measured the extent of soil erosion by Sobolev's

Table 2

Extent of soil erosion in m³/ha in relation to the type of fall plowing

Treatment	Sovkhozes								
	Spartak	Diktatura			Plavskiy				
	1948	1949	1950	Mean for 2 yr.	1951	1952	1953	1954	Mean for 4 yr.
Plowing with moldboard and coulters across the slope	14,4	17,1	14,6	15,8	18,9	3,9	1,9	7,4	8,0
The same, along the slope	26,3	17,6	21,6	19,5	25,9	5,6	2,7	11,3	11,4
Listing across the slope	1,8	7,8	3,3	5,5	4,8	2,6	0,9	2,1	2,6
Non-moldboard plowing across the slope	30,3	26,8	25,9	26,3	27,7	11,4	7,8	15,8	15,7
Discing	35,7	24,8	31,6	28,2	30,1	7,5	9,3	15,1	15,5
Stubble	11,4	13,7	18,5	16,1	15,6	4,4	3,2	10,8	8,5
Basin-listing across the slope	1,0	2,2	1,0	1,6	1,5	0	0	1,1	0,6

Note: Comma represents decimal point.

method (measurement of the volume of depressions) (Table 2). Erosion was least on the basin-listed area and greatest on the areas that had been disced and plowed without moldboard.

From our data there are 10%-18% less water-table aggregates in the 0-5 cm soil layer on the fields that had been disc harrowed or plowed without moldboard than on the fields that had been ridged or plowed in other ways. This clearly affected the extent of erosion in our experiment.

We studied the influence of basin-listing on the rate of vertical erosion of the bottom and side dimensions of a gully on the Plavskiy sovkhos between 1951 and 1954. The "Kuzin vershok" gully intersects the Plavskiy sovkhos and there is bottom and side erosion here. The catchment area at the head of this gully was basin-listed and ridged between 1951 and 1954. Before the introduction of these types of plowing bottom erosion increased and there was an increase in length of 2.5-5.0 m in the spring. The increase of erosion was greatly reduced during the years of the experiment. In 1951 it was 1.5 m; in 1952 only 0.5 m, and in 1953 no increase in length was recorded; in 1954 bottom erosion increased by 1.0 m. This is due to the fact that the runoff of water into the gully from the catchment area was greatly reduced during these years: the melt waters were collected in the basins created by plowing and absorbed by the soil. We found that the moisture of a meter thick layer of soil that had been ridged or basin-listed was increased by 3%-8% by comparison with coulter plowed areas or areas that had been plowed without moldboard or disced. This new method of autumn cultivation can undoubtedly reduce runoff in spring to a minimum and prevent water erosion of the soil. On ridged fields the melt water moves along the furrows and deposits soil particles removed from the microelevations to the microdepressions. We have measured the volume of soil particles settled on

various sectors of the slope in the Diktatura and Plavskiy sovkhos for average length, width and thickness of silt deposition (Table 3).

The data in Table 3 show that vast quantities of soil particles are shifted on a ridged field. This shifting of the soil is of great practical importance. Runoff in the spring always follows the same channels and depressions. If we do not ridge but cultivate the soil in other ways we achieve a certain levelling of the surface but this does not destroy the general micro-relief of the surface and the existing runoff channels remain and are deepened by the water. Basin-listing greatly destroys the microrelief created by the water, the damming ridges block every microhollow, the water cannot flow freely along them into the hydrographic net, but is retained and flows along the furrows. Where the height of the ridge does not conform with the depth of the microhollow, the water spills over the ridge into the next furrow. The height of the ridge is not the same everywhere. On microelevations the plow cuts a somewhat deeper sod and transforms it into a ridge in the microdepression. The height of the ridge seems to be automatically regulated: it is greater in microdepressions than on microelevations. The water accumulates in microdepressions, its flow is slowed down and its transporting capacity reduced and the suspended soil particles are settled. In normal plowing with moldboard the runoff channels are annually deepened and the surface becomes unsuitable for cultivating and harvesting machines, whereas listing gradually levels the surface of the soil.

Thus, the introduction of listing also helps to level the surface. Basin listing prevents the movement of water throughout the field, since it is retained in the basins, and the surface is therefore not levelled. Nevertheless, basin-listing is a better technique that completely halts water and solid runoff on slopes and

Table 3
Movement of soil in m³/ha on a listed field

Portion of the slope	Sovkhoszes							
	Diktatura			Plavskiy				
	1949	1950	Mean for 2 yr.	1951	1952	1953	1954	Mean for 4 yr.
Upper part of upper third	18,9	30,2	24,5	22,1	9,1	6,2	13,6	12,8
Lower part of upper third	60,2	50,8	55,5	63,4	39,2	11,5	10,8	31,2
Center slope	58,3	65,3	61,8	66,2	23,3	16,4	17,4	30,8
Upper part of lower third	50,4	45,7	48,0	50,7	30,1	17,4	22,6	30,2
Lower part of lower third	55,3	56,7	56,0	54,1	20,6	12,5	18,3	26,4
Total	243,1	248,7	245,8	256,5	122,3	64,0	82,7	131,0

Note: Comma represents decimal point.

enables one to utilize all the melt waters. Ordinary listing on unlevelled slopes may lead to the concentration of water in large streams and the development of erosion, but this danger is totally eliminated by basin-listing.

Conclusions

1. Snow retention can be advantageous (both in accumulating water in the soil and in preventing erosion) only if the measures to retain the first snow in the fields are undertaken in the autumn. Snow can then be retained in these

fields by snow plows, snow shields and other measures. Unless one takes measures to retain the first snow, it is impossible to accumulate moisture in the soil and, in addition, erosion on slopes is greatly increased.

2. Fields that have been disc harrowed or plowed without moldboard are most subject to erosion. There is less erosion on listed fields and listing helps to level the fields.

3. Basin listing greatly decreases sheet and vertical erosion; more water is accumulated in the soil than by other cultivating methods, and water runoff is practically stopped.

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A MODIFICATION OF HUMUS DETERMINATION BY THE VOLUMETRIC METHOD (FOR MASS ANALYSIS)

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Tyurin's method (4) has deservedly become one of the most common methods for volumetric determination of humus from carbon content used in the USSR. An experienced analyst can obtain absolutely reliable results when using this method to determine humus in soils or extracts (after adequate evaporation). The method is not so satisfactory when determining small quantities of carbon in samples or when slight variations in humus content need to be traced in, for example, studies of the dynamics of humus content as affected by different agricultural practices. In these circumstances, as Nikolayeva (1) and Shtatnov (5) have pointed out, it is highly important that the chromic mixture should be added slowly and carefully at an absolutely uniform rate and that heating during oxidation should be uniform. Irregular or very rapid heating gives rise to considerable deviations in parallel determinations. In addition, it should be possible when detecting slight differences in the level of a generally low organic matter content in natural waters or in water extracts from the soil to take a smaller volume of the chromic mixture and titrate the excess with a less concentrated solution of Mohr's salt: not 0.2 N but, for example, 0.02 N. This is not possible with Tyurin's method, owing to the inadequate sensitivity of the diphenylamine indicator. Our suggestion that phenylanthranilic acid should be used in this method as a more sensitive indicator simplified the procedure (2, 3). This indicator also enables one to titrate the excess of the chromic mixture with a considerably less concentrated solution of Mohr's salt (down to 0.02-0.01 N). When this acid is used, a flask of smaller volume can be employed and the titration can be carried out in the same flask, since considerable dilution of the liquid with water before titration is no longer necessary.

The test tube volumetric method described below has been developed so that Tyurin's method can be used for reliable determination of small quantities of carbon.

In this method the humus is oxidized by 0.4 N chromic mixture (proposed by Tyurin) in a boiling bath with a saturated solution of CH_3COONa or NaNO_3 at a known and fairly constant boiling temperature.

A 1.0-1.5 liter container (Fig. 1a) of enamel or heat resisting glass (from the Merefa glass

plant) can be used for the salt bath. The lid is replaced by a 1.0-1.5 cm disc of metal, fiber or wood, in which holes corresponding to the external diameter of the test tubes (23-24 mm) have been drilled. The number of holes in the disc lid depends on the diameter (disc area) of the container. A 20 cm diameter container will easily take 20-22 holes (Fig. 1b). It follows that 19-21 samples can be oxidized in one bath in one operation. Holes that do not contain test tubes must be closed with rubber stoppers or wooden plugs. A 200°C thermometer is mounted in a rubber stopper in the central hole (Fig. 1c).

The disc that covers the container must be thick enough (1.0-1.5 cm) to hold the test tubes vertically in their holes without rattling. If thin metal discs are used, two should be fixed 3.0-3.5 cm apart, the diameter of the lower disc being such that it just fits the container and clears the bottom.

The following salts can be used in the salt bath: NaNO_3 , CH_3COONa and hyposulfite $\text{Na}_2\text{S}_2\text{O}_3$. A saturated solution of NaNO_3 (222 g to 100 g of CH_3COONa (207 g to 100 g of water) at 125°C and a solution of $\text{Na}_2\text{S}_2\text{O}_3$ (307 g to 100 g of water) at 126°C (ventilation is essential). Since these solutions crystallize and solidify at room temperature, we recommend that water should be added to the bath when heating.

In the tube method the combustion temperature should be maintained at 119°-123°C. If the solution becomes highly concentrated owing to the evaporation of water, the temperature in the bath can rise considerably above 120°-125°C. It is therefore best to use sodium acetate or hyposulfite for the bath, although ventilation is essential in the latter case. At maximum concentration an NaNO_3 solution maintains a temperature of 119°-120°C well. Although it is not difficult to maintain a temperature of 119°-120°C in a boiling bath with a solution of NaNO_3 at this definite concentration, by adding water to the bath as it evaporates, the solution easily becomes supersaturated and highly condensed, in which case the temperature at the bottom of the bath can rise considerably, the solution will spatter and the tubes will overheat. It is therefore best to use sodium acetate, since its evaporation reserve is higher than in the case of NaNO_3 . For the temperature to rise from 120°-

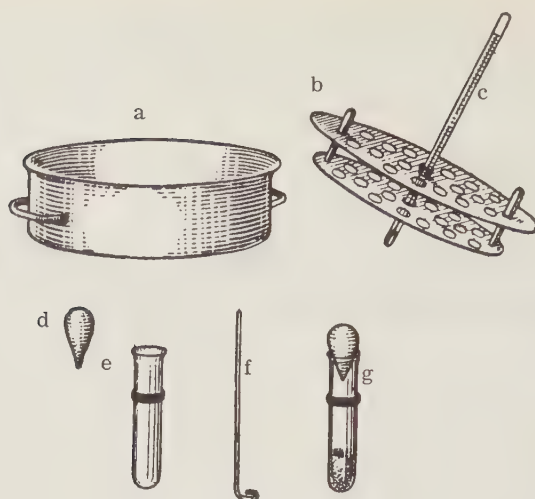


Fig. 1 - The bath for combustion of humus in tubes.

a - enamelled container; b - lid (disc) with holes; c - 200°C thermometer; d - stopper; e - tube with rubber ring; f - stirring rod; g - tube ready for placing in the bath.

125°C in this case, nearly 30% of the water in the bath at 120°C needs to be evaporated. It is normally necessary to add water to the bath to counteract evaporation once or twice in 1-1/2 hours. The level of the chromic mixture in the tubes should always be kept level with the surface of the boiling salt solution. When carefully used, the temperature of the salt bath is sufficiently constant (variations do not exceed 2°-3°C).

Any heater can be used. An electric plate with 3 settings at 300, 500 and 800 w (GOST 306-55) is suitable. Combustion of the carbon in the sample and titration with Mohr's salt of the excess chromic acid not used on oxidation are conducted in the test tubes. It is best to use 35-40 ml Pyrex glass test tubes with a diameter of 23-25 mm and a length of 14-15 cm.

The sample for humus determination is weighed on an analytical balance in a special small test tube and transferred to the test tube for combustion. After the sample has been added to the test tube, the small weighing test tube is reweighed. The weight of the sample is determined in every case by difference. Ten ml of the chromic mixture is added from a buret into the test tube with the soil sample, the test tube being revolved when the first portion is added to ensure that the whole sample is wetted. To eliminate possible error due to uneven flow of the viscous chromic mixture, its pouring must always take a fixed time (2-3 min) measured by a timer or a sand glass and the same buret (preferably 10 ml) must be used on each occasion. After addition of the chromic mixture, the test tubes are placed in the disc lid and covered with pear-shaped glass stoppers (Fig. 1d). When the required temperature is reached in the bath the lid and test tubes are placed in position on the container. Rubber

rings are placed on the test tubes to maintain their level of submersion and ensure that they do not touch the bottom of the container (Fig. 1e). These rings can be prepared from a No. 22 rubber stopper from which the center has been bored. The stopper is cut into 2-3 mm sections without removing the borer.

If the carbon content of the sample is low, a smaller amount of the chromic mixture (e.g., 3-5 ml) can be used for oxidation and a lower concentration of the Mohr's salt solution (down to 0.02-0.01 N) for titration. This increases the accuracy of the analysis as well as saving reagents and reducing costs. The concentration of the Mohr's salt solution should be such that the total volume of the liquid at the close of the back titration does not exceed the volume of the test tube. If it is impossible to complete titration in one test tube, part of the contents of the test tube are transferred to a flask, titration of the solution remaining in the test tube is completed, after which it is also added to the flask and titration of the whole solution is completed in the flask. Accurate results that agree with determination of carbon content by Knopp's method are obtained by heating for 1-1/2 hr at 120°-123°C in a salt bath. The time can be reduced on occasions to 1 hour, since the level of oxidation can be sufficiently high in this period.

After combustion the test tube container and test tubes are placed in an empty drier (or other vessel) of such a diameter that the disc fits it, and the bath is covered by an ordinary lid. After the chromic mixture in the test tubes has cooled to room temperature it is titrated with Mohr's salt solution after the addition of 3-4 drops of an 0.2% solution of phenylanthranilic acid in an 0.2% sodium carbonate solution as an indicator. Titration is

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completed when the color of the solution is changed from cherry-lilac to green by the addition of one drop of Mohr's salt solution. Since the contents of the test tubes do not boil at 120°-125°C and the chromic mixture does not therefore spatter, the pear-shaped glass stoppers need not be washed in distilled water when they are taken from the test tubes.

Since the solutions must be stirred during titration, V. P. Tsyplenkov constructed a special titration installation with an electric mixer, in which continuous stirring can be carried out during titration and observation of the color change in the titration mixture is assisted by a light bulb shining through a vertical slit in a special stand.

When there are no special installations for test tube titration, the test tube can be fastened in an ordinary stand clamp or placed in a drilled wooden block. The solution can be stirred during titration with Mohr's salt solution by raising a glass rod, the lower end of which is formed into a ring or hook perpendicular to the axis, up and down in the test tube. (Fig. 1f).

When determining oxidizability in water solutions or in soil extracts, the required volume is measured into the test tube (Fig. 1g) and the solutions are evaporated in a water bath rather than a salt bath, to avoid boiling, spattering and foaming of the solutions. In such cases 2-5 ml instead of 10 ml of the chromic mixture can be used and the excess titrated after combustion with an 0.02 or 0.01 N solution of Mohr's salt. In this way one only has to evaporate small volumes of water solution. The quantity of chromic mixture added should be such that not less than half its amount remains unused on oxidation.

All the reagents used in the test tube method for carbon determination are the same as in Tyurin's method for humus determination as modified by Simakov, using phenylanthranilic acid as the indicator (2, 3).

Preparation of the Reagents

1. 0.4 N solution of chromic mixture: 40 g of $K_2Cr_2O_7$ or 32 g of CrO_3 are dissolved in a liter of water. The solution is poured into a 2-3 liter flask and 1 liter of concentrated sulfuric acid (spg 1.84) are added.

2. 0.2 N solution of Mohr's salt: 80 g of Mohr's salt are dissolved in a liter of water containing 20 ml of concentrated sulfuric acid. Less concentrated solutions of Mohr's salt can be prepared (0.1, 0.05, 0.02 and 0.01 N) by diluting the initial solution with boiled distilled water. With each dilution of liter of water, 20 ml of concentrated sulfuric acid should be added. Bottles containing solutions of Mohr's salt should be kept from contact with the outside air by Tishchenko jars containing an alkaline pyrogallol solution or by tubes containing crystals of Mohr's salt.

3. Indicator — an 0.2% solution of phenylanthranilic acid. To prepare 100 ml of the solution, 0.2 g of phenylanthranilic acid are dissolved in an 0.2% sodium carbonate solution. To improve the solution of the phenylanthranilic

acid sample, we recommend that it should first be moistened with sodium carbonate solution until it acquires a creamy consistency and thoroughly mixed with a glass rod before the remainder of the sodium carbonate solution is added. The titration standard (normality) of the solution of Mohr's salt is found daily, in the normal manner, by titration with a solution of $KMnO_4$.

We experimented with this method, especially to find the effect of temperature variation in the range $\pm 5^\circ C$ in the salt bath on the results of carbon determination. To this end we oxidized the carbon, heating the samples in salt baths with saturated solutions: KNO_3 — boils at 115°C, $NaNO_3$ — at 120°C and CH_3COONa at 125°C. For purposes of comparison we took samples of podzolized soil in this experiment and determined carbon: 1) by Knopp's method; 2) by Tyurin's method of combustion in flasks and titration after dilution with water and the addition of H_3PO_4 with diphenylamine as the indicator; 3) by Tyurin's method of combustion in flasks and titration without the addition of water, using phenylanthranilic acid as the indicator; 4) by the combustion of the sample for 1, 1-1/2 and 2 hours in test tubes immersed in a bath heated at 115°C with a solution of KNO_3 and titrated in the test tubes with phenylanthranilic acid as the indicator; 5) as in 4), but combustion in the bath with a saturated solution of $NaNO_3$ boiling at 120°C; 6) the same as in 4), but with a saturated solution of CH_3COONa , boiling at 125°C. The results obtained are given in Table 1.

The data in Table 1 show that when carbon is determined by the test tube method, heating to 120°-125°C for 1-1/2 hours, the values obtained are practically the same as those yielded by Tyurin's method as modified by Simakov and by Knopp's method.

Later, to compare with Tyurin's method, we made a number of carbon determinations by the test tube method, maintaining the temperature at 119°-120°C in a $NaNO_3$ bath. To this end we took: 1) five samples of soil in flasks for carbon determination by Tyurin's standard method; 2) five samples in flasks for determination by Tyurin's method as modified by Simakov; and 3) five samples in tubes heated for 2 hours.

The results of the determination were statistically analyzed. The data for $M \pm t$ and t as percentages of M are given in Table 2.

The data in Table 2 show that carbon determination in test tubes by oxidation in a $NaNO_3$ bath for 2 hours at 119°-120°C yields results that are closest to those of determination by Knopp's method (1.69%) and less subject to fluctuation. This latter fact is due to the more constant even heating temperature of all the samples in the salt bath.

We subsequently made a great many carbon determinations, especially in composted samples of a laboratory experiment that we had set up with podzolized soil to reveal the effect of liming and the application of gypsum on a number of the soil's physicochemical properties. At the close of the experiment, which lasted for 9.5 months, the carbon content was determined in the soil of each of the treatments

Table 1

Carbon content in podzolized soil determined by different methods,
% of C to absolutely dry soil

Method of carbon determination	Heating time		Method of carbon determination	Heating time	C
Knopp		1,69	In test tubes in a bath	1 hr	1,58
Tyurin, with diphenylamine	5 min	1,51	With NaNO_3 -- 125°C	1 hr 30 min	1,61
Tyurin, with phenyl-anthranilic acid	5 min	1,62		2 hr	1,62
In test tubes in a bath	1 hr	1,52	In test tubes in a bath	1 hr	1,58
with KNO_3 -- 115°C	1 hr 30 min	1,57	with CH_3COONa -- 125°C	1 hr 30 min	1,60
	2 hr	1,56		2 hr	1,64

Note: Comma represents decimal point.

Table 2

Carbon content in podzolized soil

Method of determination	C as a % of M	t	t as a % of M
Tyurin's method with diphenylamine	1,51	$\pm 0,020$	1,32
Tyurin's method with phenylanthranilic acid	1,62	$\pm 0,014$	0,86
In test tubes heated for 2 hr at 120°C	1,67	$\pm 0,010$	0,60

Note: Comma represents decimal point.

given below. Six samples of each (approx. 0.200 g) were weighed out on an analytical balance. The oxidation was conducted in a bath with a solution of CH_3COONa , preheated to 120°C . The temperature was subsequently maintained between 120°C for 1-1/2 hours. A blank test was made at the same time. After the carbon content in the soil of all the seven treatments had been determined in this way, we once more took two samples of the soil from each treatment and oxidized them in the same manner, but simultaneously in one procedure. We thus tested whether our findings could be reproduced. The results are given in Table 3.

The data in Table 3 show that the results can be reproduced with a high degree of agreement. We were able to assert fairly confidently from our data that excess of lime and gypsum lowers the rate at which organic matter is decomposed in podzolized soil. It was not accidental that there were slight deviations (no more than a few tenths of one per cent) in the carbon content of the soil between the treatments of the experiment that had received CaCO_3 at 0.5 and 1.0 of hydrolytic acidity.

These differences are an exact reflection of the real variations in its content in the soil of these treatments on composting, since the deviations of the arithmetic means were: $D_{3-2} = 3.22 - 3.05 = 0.17 \pm 0.025$; consequently the

reliability is $W = \frac{0.17}{0.025} = 6.8$. The same thing

is observed in the gypsum treatment. We can state with a fair degree of confidence that gypsum alone makes the conditions less favorable for the decomposition of organic matter, since

$D_{4-1} = 3.18 - 3.12 = 0.06 \pm 0.027$, when $W = \frac{0.06}{0.027}$

$= 2.22$. When parallel analyses yield such close results in carbon determination we can study humus dynamics even when the period is short and the variations in its content are slight.

In addition to determining the humus in soil samples, we also determined carbon in water solutions of different concentrations of humic acid. The water solutions of humic acid were first made weakly alkaline with a NaOH solution, after which they were evaporated in flasks to determine carbon by Tyurin's method or in test tubes. When oxidizing in test tubes, no more than 2.50 ml of 0.4 N chromic mixture were added from a microburet. Oxidation was effected in a bath with NaNO_3 at $119^\circ - 120^\circ \text{C}$. An 0.04-0.03 N solution of Mohr's salt was used for titration.

The carbon content in 40 ml of the initial solution was first found by Tyurin's method to be 1.35 mg. Thus the concentration of this solution was 0.0337 g/liter or 33.7 mg per liter. We took 5 samples of 10 ml each in flasks from this solution for carbon determination by Tyurin's

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Table 3

Carbon content in composted samples

Exp. No.	Treatments	C as a %	Average for 2 determ.	Average for 6 determinations	
				M	t
1a 1b	Control	3,12 3,13	3,13	3,12	0,022
2a 2b	CaCO ₃ , 0.5 of hydrolytic acidity	3,05 3,09	3,07	3,05	0,023
3a 3b	CaCO ₃ , 0.5 of hydrolytic acidity + 25 mg CaSO ₄	3,07 3,15	3,11	3,07	0,004
4a 4b	25 mg CaSO ₄	3,18 3,19	3,19	3,18	0,015
5a 5b	CaCO ₃ , 1.0 of hydrolytic acidity	3,23 3,23	3,23	3,22	0,009
6a 6b	CaCO ₃ , 1.0 of hydrolytic acidity + 25 mg CaSO ₄	3,24 3,29	3,27	3,24	0,013
7a 7b	CaCO ₃ , 1.0 of hydrolytic acidity + 400 mg CaSO ₄	3,26 3,33	3,29	3,30	0,011

Note: Comma represents decimal point.

Table 4

Carbon content in 10 ml of a water solution of humic acid

Method of determination	C mg M	±t mg.	t as a % of M
Tyurin's method with phenylanthranilic acid	0,33	0,011	3,3
Test tube method, heated 1 hr	0,36	0,009	2,5
The same, 1 hr 30 min	0,35	0,005	1,4
The same, 2 hr	0,36	0,009	2,5

Note: Comma represents decimal point.

method as modified by Simakov and 9 samples of 10 ml each in test tubes. The test tube samples were divided into 3 groups of 3. The first series of test tubes were heated in the bath for 1 hour, the second for 1-1/2 hours, and the third for 2 hours. The results are given in Table 4.

The data in Table 4 show that carbon can be determined with great accuracy by the test tube method even in solutions that only contain

33 mg of carbon per liter. This concentration does not exceed that of carbon in natural soil solutions or in water extracts from podzolized soil.

We shall give data for carbon determination in a highly dilute alkaline humate solution. 10 ml of this solution were evaporated in test tubes in a water bath until dry; 3 ml of chromic mixture were then added to the test tube and heated for 1-1/2 hours in a bath with CH₃COONa

Table 5

Carbon content in the soil determined by various methods
(average of 3 determinations)

Method	Soil	C	C w. Ag_2SO_4
		as percentages	
Knopp's	Chernozem	4,01	4,45
Tyurin's	»	3,91	4,05
Test tube			
Heating, 1 hr	»	3,96	4,20
Heating, 1 hr 30 min	»	3,98	4,14
Heating, 2 hr		4,02	4,25
Test tube	Podzolized		
Heating, 1 hr	»	1,56	1,71
Heating, 1 hr 30 min	»	1,58	1,75
Heating, 2 hr	»	1,67	1,80

Note: Comma represents decimal point.

at 120°-122°C. Back titration was conducted with an 0.05 N solution of Mohr's salt. The experiment was repeated 9 times. The result in all the test tubes was identical: 0.209 mg of carbon¹, i. e., 20.9 mg of carbon per liter. Second example: 5 ml of a humate solution were evaporated in tubes in a water bath. 2 ml of chromic mixture were added to the dry residue and oxidized in a bath with CH_3COONa for 1-1/2 hours. Back titration was carried out with an 0.05 N solution of Mohr's salt. The experiment was repeated 5 times. An identical result was obtained in all the tubes: 0.101 mg of C, i. e., 20.2 mg of C per liter.²

These results show that the test tube method for carbon determination is also useful for determination of the carbon content (oxidizability) in natural waters. This method can easily be used by expeditions, since the salt bath can be heated on the primus or kerosene stove. In conclusion, we note that the high level of agreement between replicates was also obtained when determining the carbon of high-humus content soils (e. g., chernozems) by this method (Table 5).

The method was not suitable for the determination of carbon in peats, since light plant residues float on the surface of the chromic mixture in the test tubes and do not mix in and are not totally combustible, since the mixture does not boil.

Note that it is not always essential to add 10 ml of chromic mixture in humus determination by the test tube method. If the humus content of the soil is low, as in podzolized soils, 2.5-3.0 ml will suffice for 0.1 g of soil and the excess remaining after ignition can be titrated back by a weaker solution of Mohr's salt. One

should bear in mind that after combustion in the test tube not less than half the amount of 0.4 N chromic mixture used should be left, i. e., its concentration at the end of oxidation should be not less than 0.2 N, as Tyurin has indicated (4).

Higher results are obtained if Ag_2SO_4 is added to the chromic mixture as a catalyst when oxidizing organic matter in test tubes, as in Tyurin's initial method and when determining carbon by Knopp's method, since it ensures more complete oxidation of the organic matter (Table 5).

It is clear from the foregoing that the volumetric test tube method for carbon determination developed in the soil science faculty of Leningrad University is simple, suitable for mass analysis, and capable of yielding highly reproducible results. It can be used to determine humus in various soil extracts, and also to determine carbon (oxidizability) in natural waters; the method can also be used by expeditions.

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¹Analyst Yu. Lapko-Danilevskiy.²Analyst L. K. Zhilina.

A TITRATION DEVICE FOR THE VOLUMETRIC METHOD OF HUMUS DETERMINATION

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A test tube volumetric method for the determination of humus from the carbon in soils and solutions (oxidizable) has been developed in the soil science faculty of the Leningrad State University. The method is highly accurate and only requires small amounts of the reagents.

When determining humus by this method, the entire analysis (combustion and titration) is carried out in the same vessel (a small test tube) since the sample does not have to be diluted with water when titrating with Mohr's

salt solution. In order to speed up the process and facilitate mixing when titrating with Mohr's salt solution, we designed and tested a special titration device, consisting of a buret, stand, a light source, and an electric motor attached to a spiral glass mixer. The device is shown in Figure 1.

The apparatus here described is easy to use and simple to construct and can be quickly and economically set up in any laboratory.

A small box of suitable size and a metal rod

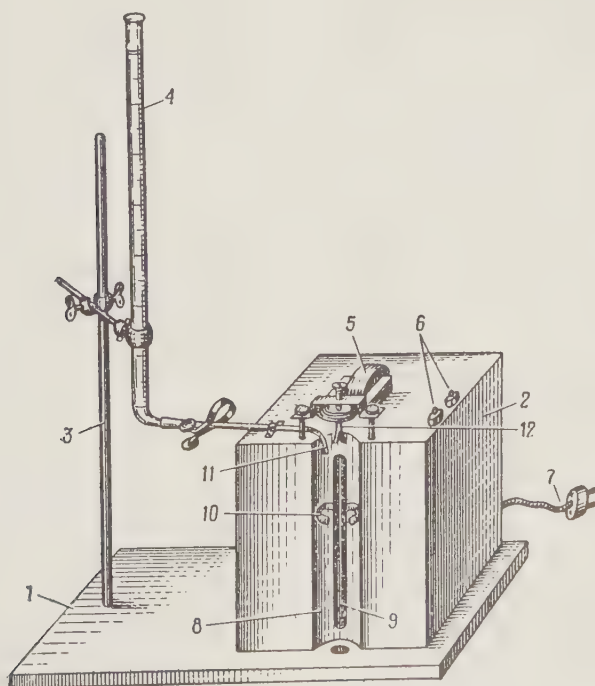


Fig. 1.-General view of titration apparatus

- 1 - base; 2 - box; 3 - stand; 4 - buret; 5 - EDP-56 motor; 6 - switches; 7 - electric cord and plug; 8 - recess for test tubes; 9 - vertical slit; 10 - clips for holding test tube; 11 - mouth of buret; 12 - rubber spindle and clamp for mixer.

for the buret are mounted on a base of wood or other suitable material.

Either an ordinary or an automatic buret (as available) is mounted on the rod and the lower tube is horizontally secured to the top of the box, with its end over the test tube so that drops of Mohr salt fall into the test tube and are immediately mixed with the solution being titrated when the mixing rod is revolved. The box on which the motor and mixer and switches are mounted can be made of a board or plywood, and the front face can even be a thick cardboard painted with oil paint. The test tube is fastened by metal clips into a recess in the front face of the box. The light source is placed inside the box and illuminates the titration through a vertical slit in the recess on the front face. We used an ordinary light bulb and current

from the mains reduced by a "Gnom" bell transformer. The light slit was covered by frosted glass or tracing cloth to ensure even illumination of the mixture in the tube.

The electric motor actuating the glass spiral mixer is fixed to the top of the box. The EDP-56 motor, which is easy to obtain, is suitable. A band drive is used between the motor and the mixer. The switches controlling the motor and the light source are mounted on the top of the box.

The apparatus works from a 120-200 V ac mains current.

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A LETTER TO THE EDITOR - CRITICISM OF V.V. DOKUCHAYEV'S THEORY OF FACTORS

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The great Russian soil scientist Dokuchayev often had to defend his views on soil formation. One has only to recall P. A. Kostychev, who, in Dokuchayev's words "denies every connection between the relief of a locality and the thickness of the local soil" (3, p. 395) and "almost every relationship between steppe vegetation and local climate" (3, p. 392). One has, however, to know the hypotheses that Dokuchayev was defending, which remain unchallenged, to understand the deep nature of the disputes between these two scholars. Now after Dokuchayev's "theory of factors" has been in existence for 75 years it has once again been suggested that there are "weak" sides to this theory. Thus, V. V. Ponomareva finds two weak sides, one of which is that "when one is speaking, for example, of the factors in the life of plants or other organisms, it is clear that they affect the organism and are the essential external conditions for its vital activity. In relation to the factors of soil formation, which are very diverse in their nature (organisms, parent materials, relief, climate, time) one is not clear what they affect. The parent material? In that case, the parent material would no longer be a factor but would be an object influenced by the remaining factors. The soil? But it does not develop before the process of soil formation, the essence of which we are now trying to understand. One can hardly accept, as sufficiently clear or correct, the idea that soils are formed as a result of the combined action of the factors of soil formation at the site of their interaction (4, p. 49).

Ponomareva suggests that the biological factor should be taken as the only factor in soil formation. The others (parent material, climate, relief) are only the environment, the conditions in which the biological factor becomes apparent. In other words, the environment forms the vegetation and the vegetation forms the soil. In drawing an analogy between two completely different natural acts — the life of an organism and the creation of a soil — Ponomareva forgets that the reader will ask himself on what the factors of the origin of life (organisms) on Earth acted. On water? In that case water would no longer be a factor but the subject of the action of the remaining factors. On the organism? It does not exist before the process of the creation of life, the essence of which we are now trying to penetrate.

The whole cause of the confusion is that research workers mix up their concepts.

The "soil-forming process" is sometimes considered as a process of the creation of a soil, sometimes as that of the historical formation and development of soils and sometimes as the life of contemporary soils.

Dokuchayev treated the soil-forming process as one of the formation and development of contemporary soils, taking place under the influence not of any single factor but of many interrelated and interdependent factors. It is difficult and perhaps even impossible to find any phenomena in nature that are influenced by one factor only, and such complex natural facts as the origin and development of soils on the Earth can certainly not be due to a single factor.

Nevertheless, what did the factors of soil formation influence? Always the soil. But it "did not develop before the process of soil formation." We shall try to resolve this problem. In Ponomareva's view, plants "form the substrate necessary for their life — the soil — in symbiosis with microorganisms" (4, p. 50). The question arises as to whether life or its substrate appeared on the Earth first. The most probable answer is the substrate, which made life possible.

We shall not postulate that life originated on dry land. If we did there would be nothing to discuss. We shall assume that the waters of the ocean were for some time the only substrate in which life existed. Figuratively speaking, the water was the "soil" for the first organisms. Who would assert that water and the compounds dissolved in it were created by living organisms solely because they were essential to their life? Subsequently life spilled over from the ocean to the dry land. The primary organisms found a substrate that satisfied their inherited requirements. In adapting themselves and changing their hereditary basis they exerted a considerable influence on the substrate and became a factor in soil formation. In the course of evolution contemporary vegetation has been developed from the primary organisms and contemporary soils derive their history from the substrate on which the primary organisms settled. It therefore seems to us to be more correct to say that plants do not form the substrate but transform

it, in as far as wherever life came from to the dry land it could not create a substrate for itself in advance and then occupy it.

Soil scientists begin the history of the soil-forming process with the weathering of rocks. In this case the rock is no longer a factor but a subject for the action of the other factors. In so being it does not cease to be a factor that influences the soil-forming process and, as is known, a number of the properties of soils can be explained purely in terms of the influence of the parent material.

The second weak side to the theory of factors is that the theory seems to treat the factors as "of equal weight or significance in their effect on something" (4, p. 49). But nobody has ever treated the factors as being of equal weight. The factors are indispensable, but primary and secondary factors can be distinguished. This was stressed by Dokuchayev himself: "Natural vegetation (which we know to be one of the most importance soil-forming factors)... " (2, p. 400).

Ponomareva writes that "the existence in the biosphere of living autotrophic organisms — green plants, which cannot exist without the mineral elements of the Earth's crust and which therefore implant themselves in its upper layer — is the sole and direct cause for the origin and development of our Planet's soil" (4, p. 49). We have cited this passage to show the degree of confusion between these two factors in soil formation — vegetation and the Earth's crust (parent material) and we can only express our astonishment that Ponomareva should make the following deduction: "...neither parent material, nor relief, nor climate can in themselves either singly or together form soils and they are not the causes of their formation" (4, p. 49). But can organisms themselves form soils either alone or together? Can vegetation alone explain all the diversity of the soils? Can the biological factor alone explain why we have grey forest soils beneath a forest in one case and podzols in another? Finally, how does one answer the question of whether bog soils form bog vegetation or whether bog vegetation is due to bog soils?

V.R. Vil'yams wrote: "We know that the natural factors of soil formation were neglected by scholars before Dokuchayev's time." Dokuchayev's merit was that he did not consider the soil from the point of view of any one factor but considered the combined effect of "five natural factors" (1, p. 17). Ponomareva acknowledges the vast influence of other factors (conditions) on soil formation, but considers that they are "manifested, above all, through their influence on the organisms, and then simultaneously on the process of soil formation due to the organisms" (4, p. 53). Can we accept such an opinion? Clearly not, for the simple reason that the substrate had in some measure begun to be formed before the organisms appeared there. It seems to us that acceptance of Ponomareva's view would involve rejection of the concept of the soil as an independent natural body that has accumulated a number of external environmental factors and has developed under their influence from an initial simple substrate to the complicated soil pattern that exists throughout the globe today.

In closing this letter I should like to point out that I am not opposed to creative development of Dokuchayev's "theory of factors" but am against revisionism, whatever its source. I am in favor of a scientific and accurate reflection of reality and am opposed to ill-founded views on what are factors and what are conditions.

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CHRONICLE

ALEKSEY SEMENOVICH VOZNESENSKIY

By the Georgian Research Institute for Hydrotechnical Engineering and Melioration, Academy of Agricultural Sciences, Georgian Soviet Republic

Professor Aleksey Semenovich Voznesenskiy, the eminent soil scientist, died on June 19, 1959, following a serious illness. He was 72 years old. Professor Voznesenskiy was an Honored Scientific Worker of the Georgian Soviet Republic, a doctor of agriculture and the Director of the Soil Melioration Laboratory of the Georgian Research Institute for Hydrotechnical Engineering and Melioration.

After graduating from the Moscow Agricultural Institute, Voznesenskiy began his scientific and teaching activity in 1916 as a soil scientist in a hydrological department in the Caucasus, and as a teacher at the Tiflis Agricultural Technical Institute.

Voznesenskiy did the greater part of his scientific and productive work in the Georgian Research Institute for Hydrotechnical Engineering and Melioration (formerly ZakNIIVKH). It was here in 1928 that he set up the soil laboratory that he was to direct until the last days of his life.

Voznesenskiy's scientific and productive research was very extensive and varied. There were three main trends to his research: 1) studies of the soils of Georgia and the other Transcaucasian republics to reveal the state of the agricultural land; 2) studies concerned with the solution of important problems in hydrotechnical engineering, soil melioration, the prevention of erosion, etc.; and 3) studies on the development of new methods and approaches for studying soils in relation to scientific achievements and the requirements of agriculture.

Voznesenskiy's works are of both practical and theoretical importance.

His physicochemical study of soil materials in the Mingechaur district, the object of which was to assess the feasibility of constructing a high pressure dam at the Minchegaur hydroelectric station, was highly praised by important scholars and widely used in the planning of the dam. Voznesenskiy determined the degree of erosion for the most widely distributed soils in Transcaucasia, proposed an index for the comparative evaluation of soils from this feature and developed the basic theoretical postulates for a scientific theory of measures to control erosion. His research results were presented as a monograph,

Voznesenskiy developed an original approach to the prevention of water losses by percolation, by the artificial gleying of soils and soil materials, and justified the method theoretically. The essence of the measure is to reproduce a reduction process in the organic matter contained in the soil material. It has been found to be highly efficient in controlling percolation.

Owing to his skillful allowance for environmental conditions, the meliorative works that he directed in the Alazan valley were effective on worthless salined land. Leaching operations were related to deep drainage on the plowed field in the summer and autumn, when the ground waters lay at their deepest level and the soil layer was fissured.

Voznesenskiy developed a simple method for comparative evaluation of soils and soil materials from the hydrophilous nature of their fine fraction. The method is used to classify soils and soil materials in relation to water stability, water yield and salt-yield and other factors.

His approval of the tensiometer, which he applied to soil hydrology research, was of great practical importance. In the last years of his life Voznesenskiy was concerned with the utilization of the drained lands of the Kolkhida lowland and developed agricultural practices for improving the water-physical properties of the soils and increasing their fertility.

Voznesenskiy produced more than 35 published works and 100 manuscripts. He taught and worked at institutes of higher education in Georgia for more than 30 years.

Voznesenskiy's long and creative activity has been highly praised: he was awarded the Order of Lenin and Defense of the Caucasus and the medals "For Outstanding Work in the Great Patriotic War of 1941-1945."

His pupils, comrades and friends will always remember Aleksey Semenovich as an important, principled and profound scholar, a fine teacher, a sympathetic comrade and a modest man who was devoted to his work.

REPORT OF THE ACTIVITY OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS IN 1959

N. A. RAZORENOVA

Membership and Structure

On December 1, 1959 the Society had 2804 members, (204 more than in 1958). The increase in membership is due mainly to the admission of young specialists. The Society has 22 corporate members — scientific research institutes, institutions of higher education and productive organizations.

At the present time the Society has 15 filials in the Union Republics, 30 sections in large towns in the RSFSR and 13 groups in educational institutions, research institutes and productive organizations in Moscow. Similar groups have been established in the most important filials and sections — in the Ukraine, Byelorussia, Leningrad, Kazakhstan, Georgia, the Northern Caucasus and Voronezh.

Three new sections (the Kemerov, Buryat and South Sakhalin sections) have been organized.

The Society is directed by the Central Council and its Presidium, headed by Academician L. V. Tyurin, the President of the Society.

Seven standing commissions of the Presidium lead work in the main branches of soil science: physics, chemistry, biology, soil fertility, soil genesis, the classification and geography of soils, and melioration and soil mineralogy.

A new standing commission, the dictionary commission (Chairman Professor A. A. Rode), has been set up to compile a definitive soil science dictionary.

In addition, the Presidium has set up an organization committee in the past year to prepare for the 7th International Congress of Soil science. At its meeting on January 27, 1959 the Bureau of the Department of Biological Science of the USSR Academy of Sciences approved the 37-member organization committee headed by Academician L. N. Antipov-Karatayev. The organization committee includes representatives of the filials, the largest Moscow groups, including the Dokuchayev Soil Institute of the USSR Academy of Sciences, the Moscow State University, the Timiryazev Agricultural Academy, the All-Union Research Institute for Fertilizers and Agronomical Soil Science and the

Chairmen and Secretaries of the standing commissions.

Soviet soil scientists are represented in the international organization by 67 members and 10 organizations.

The Activity and Organs of the Presidium

During the year the following questions were examined at the meetings of the Presidium: 1. Increasing the activity of the All-Union Society of Soil Scientists in connection with the decisions of the 21st Congress of the CPSU (Communist Party of Soviet Union) and the December plenary session of the CPSU. 2. The working plans of the Society's filials and sections. 3. Approval of the newly organized Kemerov, Buryat and South Sakhalin sections. 4. The convening of regional soil meetings in Voronezh, Ufa and Ordzhonikidze by the respective filials and sections. 5. Preparation for the 7th International Congress of Soil Science.

The standing commissions held 40 meetings in the course of the year. Papers presented dealt with aspects of the water regime of soils, the biological cycle and its role in soil formation, the exchange of radioactive isotopes between the soil and plants, the activity of soil enzymes, biological fixation of nitrogen, evaluation (site index) of soils, the genesis and classification of brown forest soils and other subjects. In addition to the members of the Society from Moscow, representatives of the Armenian, Moldavian and Leningrad filials and of the Kirov agricultural institute presented papers to commission sessions.

All the commissions are assisting in the preparation of the soil science dictionary. The sections on physics, mineralogy and soil melioration are already prepared for publication. The other sections of the work are at various stages of completion, but are, in general, behind schedule. In addition, editing of the Russian text for the new edition of the International Soil Science glossary has been completed.

Commission V, which has been concerned with organizing collective work on soil diagnosis, has prepared a plan for a "card index of the features of the main soil types" and has sent it to the filials and sections for discussion. The

draft will be revised in the light of the comments received and copies of the revised card index will be prepared for general use.

Scientific Relations with Foreign Countries

The organization committee, assisted by the standing commissions, has done a great deal of serious work in preparation for the 7th International Congress of Soil Science.

The members of the Society have been kept informed through *Pochvovedeniye*, and by special letters about the meeting of the International Congress and the conditions for participation. More than 70 papers have been assembled and considered at meetings of the organization committee. The 62 papers selected were prepared and sent to press for publication as the collected papers of Soviet soil scientists to the 7th Congress (35 printer's sheets).

Commission V of the Society took part in the preparation and running of an international working gathering called by the Dokuchayev Soil Institute of the USSR Academy of Sciences to prepare a soil map of Europe. The soil map is being prepared for the forthcoming Congress in conformity with the wishes of the preceding 6th Congress, and the section that includes the USSR and the People's Democracies is being prepared by the Dokuchayev Soil Institute. The meeting was attended by a group of authors from the Institute and Commission V of the Society headed by Academician I. V. Tyurin, by representatives of the soil organizations of Bulgaria, Hungary, the German Democratic Republic, Poland, Rumania and Czechoslovakia, and by representatives from the soil center in Belgium and England. The main task of the meeting — to coordinate the work and to agree on the conventional signs to be used in the map — was achieved. A communique on the results of the meeting was published in *Pochvovedeniye*, No. 12, 1959.

Academician Tyurin, the President of the All-Union Society of Soil Scientists, and corresponding member V. A. Kovda, the Vice-President, who were elected at the preceding 6th Congress as members of the organizing committee for the 7th Congress, have been continually involved in preparing for the Congress and working out its program. Soviet scholars have included Academician Tyurin's brilliant paper "The role of soil science in the agricultural production of the USSR" in the program. The following papers have also been included in the extended commission sessions: Academician I. P. Gerasimov "The new soil map of the world;" corresponding member V. A. Kovda and Dr. Ye. V. Lobova "The soil map of Asia;" Drs. Ye. N. Ivanova and N. L. Rozov "Classification of the soils of the USSR." All requests for papers from Soviet soil scientists presented to the program committee in July 1959 have also been met (51 papers). All papers have now been prepared in accordance with the regulations and sent to the organization committee of the Congress.

During the year Academician Tyurin attended the annual meeting of the German Society of

Soil Scientists.

Activity of the Society's Filials and Sections

The filials and local sections have conducted a wide range of activity to ensure creative contact between specialist soil scientists, agricultural chemists and agronomists in different institutes and organizations, to improve the scientific knowledge of the Society's members and to popularize scientific achievements in soil science and scientific assistance to production.

In the countless papers and contributions to discussion at the meetings of the filials and sections in the past year a great deal of attention has been paid to classification, site indexing and the chemistry of soil, large-scale soil mapping and agricultural soil regionalization by Republics, subdistricts and regions. These aspects are reflected in the work of almost all filials and sections.

The instruction concerning large-scale soil mapping in kolkhozes and sovkhoses and the use of soil maps worked out by the All-Union Research Institute for Fertilizers and Agronomical Soil Science and VASKHNIL and circulated to institutes and organizations has been discussed in detail at the scientific sessions of many filials and sections.

The melioration of salined soils has been discussed by the Ukrainian, Georgian and Uzbek filials, and by the Stalingrad, Omsk, Kuybyshev, Novosibirsk and other sections. Particular attention has been paid to aspects of preventing soil erosion in the Armenian and Georgian filials and in the Voronezh, Bashkir, Irkutsk, Kazan' and Kuybyshev sections.

A considerable part of the scientific papers and communications has been devoted to agricultural chemistry and the use of fertilizers, especially in the Georgian, Latvian, Lithuanian and Estonian filials and in the Altay, Far Eastern, Voronezh, Irkutsk, Krasnodar and Ryazan' sections. The use of microelements has been studied in some filials and sections.

Scientific knowledge of the soil has been popularized by public lectures, radio talks and press articles. Most work of this type has been done in the Ukrainian, Azerbaydzhanian, Georgian, Kazakh, Leningrad, North Caucasian and Tadzhik filials and in the Bashkir, Gorky, Kuybyshev, Penza, Rostov, Stalingrad and Tomsk sections of the Society.

Many members of the Society who are scientific workers have helped working soil scientists to carry out soil studies and to write up their materials by consultations and assistance on method.

In the past year the filials and sections have held a number of regional soil gatherings on aspects of classification and site-index, the establishment of agricultural soil regions, the use of fertilizers and other questions. Meetings of this type have been held by the Ukrainian, Estonian, Tadzhik and Kirgiz filials and by the North Caucasian, Bashkir, Voronezh, Gorky

and Kazan' sections.

The Altay and Mari sections have helped institutes to set up soil museums: new exhibits have been added to existing soil museums in the Ryazan', Petrozavodsk, Komi and North Caucasian sections.

The Lithuanian and Latvian filials and the Irkutsk, Kiev, Petrozavodsk and Mari sections have held soil excursions attended by specialists from adjacent Republics and regions.

Publications

The first delegate congress of soil scientists decided to publish 500 copies of its "Proceedings." Orders from the filials and sections and from organizations, libraries and individual members of the Society are now being supplied. The second volume of the Proceedings is being prepared for publication. The "Collected Papers of Soviet soil scientists for the 7th International

Congress of Soil Science" have been passed for press.

An information bulletin on the meetings of the Society's standing commissions, containing a brief summary of the scientific papers and discussions, has been duplicated.

Work is proceeding on the soil science dictionary, which the compilers intend to complete early in 1960. V. M. Kaluzhskaya's pamphlet "A guide to the ash analysis of plants" has been published. In the year just past the Bashkir section has published the "Bulletin of the Bashkir section of the All-Union Society of Soil Scientists" and the collected papers presented to a regional conference of soil scientists in the Southern Urals. The Voronezh section has prepared the materials of a scientific conference of soil scientists from the central chernozem regions for publication. The Tadzhik and Ukrainian filials are preparing collections of papers for the 7th International Congress of Soil Scientists, which will be published in 1960.

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